ASTRONOMY®

WILL SUPERNOVA 1987A SHINE AGAIN?

February 1992 U.S. $2.95
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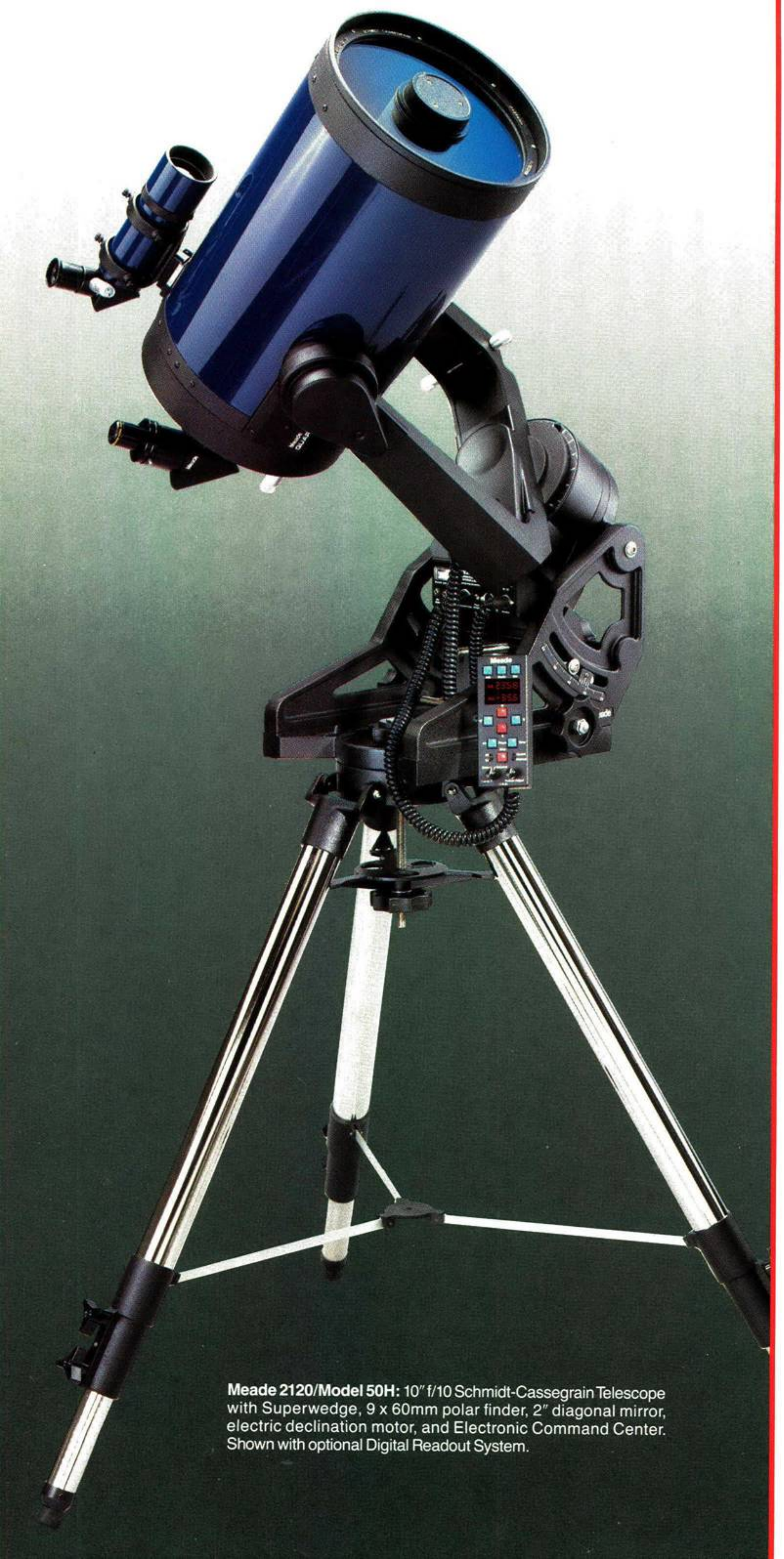
Casting Light on Dark Matter

Astrophotos: Don't Waste Those Moonlit Nights

ICD 08070

The Dumbbell Nebula Goes Electronic



Meade 2120/Model 50H: 10″ f/10 Schmidt-Cassegrain Telescope with Superwedge, 9 x 60mm polar finder, 2″ diagonal mirror, electric declination motor, and Electronic Command Center. Shown with optional Digital Readout System.

Meade® SC Opti

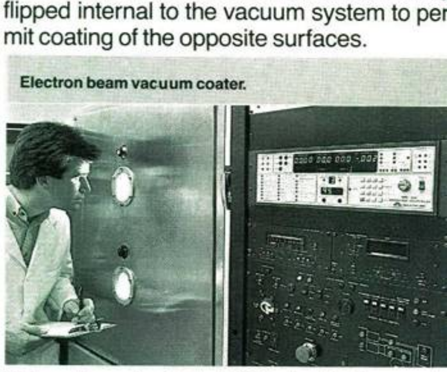
Keeping up with modern optical techno ogy is an expensive process at Meade Instruments—but one which is absolutely vital to our continuing leadership in the production of Schmidt-Cassegrain optica systems. Long recognized as the finest commercially-produced Schmidt-Cassegrain optical systems available, Meade SC optics have recently been still further refined by the addition of important new equipment and processes—additions that assure the potential Meade SC purchaser that his or her telescope is, without qualification, state of the art.

New Super Multi-Coating (SMC): Now included as standard equipment on the correcting plates of most Meade 4″, 8″, and 10 SCT models, the deep-purple Supe Multi-Coating produces the highest ligh transmission of any antireflection coating in the industry.

Super Multi-Coating on the Meade 8″ 2080/Model 50.

At our Costa Mesa coating facility, Meade technicians use the latest electron beam vacuum coating systems to deposit, at 550°F the hard, multi-layer chemistry of the SMC—a coating that perceptibly increases image brightness and contrast. Seven correcting plates can be coated on one plate side simultaneously; the plates are then automatically flipped internal to the vacuum system to permit coating of the opposite surfaces.

Electron beam vacuum coater.



"I have been absolutely delighted with the superior performance of the Meade 10" Schmidt-Cassegrain. The optics are superb. At a recent star party Omega Centauri was resolved into thousands of tiny pinpoints into its core...Many said they were thrilled not only to see so much spiral structure in the Whirlpool Galaxy (M51) but also to see the fain bridge between the two components of M51."
—L. J. Alfonso, Boca Raton, FL

Primary Mirror Central Coring: Before Meade 4″, 8″ and 10″ SC primary mirrors can be polished and figured to within exacting optical tolerances, the central perforation, or

al Performance...“Superior...Superb...Breathtaking.”

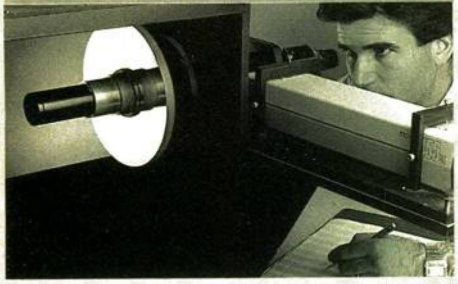
core, of each mirror blank must be precision diamond-ground into the blank. In the Meade optical shaping department this operation is performed on a 5-axis Computer Numerically Controlled (CNC) glass-machining center. The result is a mirror perforation (ready to accept the primary mirror baffle and focusing mechanism) that is within arc minutes of perfection—a precision that, with minor final adjustment by optical alignment technicians *(see below)*, virtually eliminates mechanically induced aberrations in the Schmidt optics.

CNC coring of SC primary mirrors.

“When unpacking my Meade 10″ SCT I realized that the amount of work which had gone into making this instrument was incredible...every detail was perfect down to the last nut and bolt. On the first clear night I took the scope out to check the optics. Quite simply the views were breathtaking! Star images matched textbook versions letter for letter, showing perfect symmetry in and out of focus.”
—J. Spang, Chorely, England.

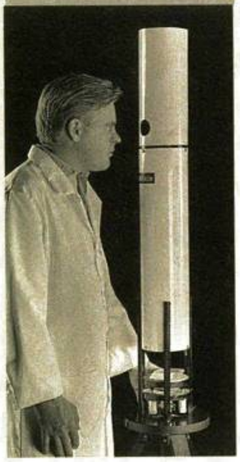
Optical Testing: As each Meade 3-element SC optical set (primary mirror, secondary mirror, and correcting plate) progresses through the grinding, polishing, and final hand-matching stages of development, it is continuously tested and re-tested for zonal irregularities, smoothness, and correction. Intermediate testing is performed using the Foucault and Ronchi methods; final diffraction image testing is done with a double-pass laser autocollimator that passes an intense pinhole of monochromatic light through the 3-element system *twice*, enabling the technician to detect errors (at an effective magnification of 1000X) beyond the observable limit of the field user. If we seem unusually confident in the capabilities of Meade Schmidt-Cassegrain optics, it is because we know that every optical set is put through this battery of over 30 separate optical tests and inspections before the optics are mounted in the optical tube and shipped to you.

Autocollimator testing of an 8″ SC system.



“Using my Meade 8″ SCT under just fair seeing the 1.0 arc sec double Zeta Boötes was beautifully separated, with plenty of dark space between the circular Airy discs. At lower power the four stars of Epsilon Lyrae were also cleanly separated and a beautiful sight, with all in the same field.”
—R. Knight, Stow, OH

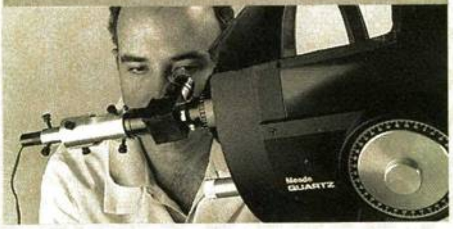
Interferometric testing of diagonal flats.



Diagonal Flat Testing: Integral to the functioning of any high-performance Cassegrain system is the optical smoothness and flatness of the diagonal surface. Every Meade diagonal mirror is tested for flatness on a Fizeau laser interferometer; mirrors which pass this test are coated with enhanced aluminum and mounted in their machined diagonal housings.

Optical Alignment: Finished, individually matched 4″, 8″ and 10″ SC optical sets are sent to the optical alignment department, where each set is placed into a special cut-out optical tube that permits rotation of the optical elements about the optical axis. (The relative rotational orientations of the Schmidt-Cassegrain primary mirror, secondary mirror, and correcting plate are *not* arbitrary.) Rotation of the optics, while the technician observes an artificial starpoint under controlled laboratory conditions at high power, yields the unique relative orientation that cancels out any residual aberrations of the system. With optimal orientation thus fixed, each optics set is placed into the machined housings of its optical tube. The optical system is once again tested for roundness, regularity, and consistency of the diffraction image inside and outside of focus. Only after passing this final test is an optical tube system ready to become part of a Meade Schmidt-Cassegrain telescope.

Rotational orienting of 10″ SC optics.



“As a former staff member at Mt. Wilson and Palomar Observatories, I have had access to some of the finest optics ever produced. The Meade 10″ f/6.3 2120 is the most impressive commercial instrument I have yet seen. Under critical examinations, stellar diffraction patterns are superb both inside and outside of focus. Focal images are sharp and crisp; in applications where high contrast characteristics are important (such as in observing the ‘eyes’ of the Owl Nebula, M97, or structural variations in the main spiral arm of the Whirlpool Galaxy, M51) the telescope performs impressively. The image of Saturn is beautifully defined, showing subtle belt detail and the crepe ring with surprising boldness for a 10″ telescope.”
—Paul Roques, Williams, AZ

Final quality control inspection.

Quality Control: As part of the final quality control inspection, an inspection which also includes detailed checkout of the telescope's mechanical and electronic functioning, each optical system is examined for any coating sleeks or scratches which may have occurred in the manufacturing process. Telescopes which pass this series of tests are then packed for shipment to authorized Meade dealers throughout the world.

Every Meade Schmidt-Cassegrain telescope must pass more than 135 optical, mechanical, and electronic tests, inspections, and quality control procedures before it is judged ready for shipment. If you're as committed to optical quality and performance as we are, then see what a Meade 4,″ 8,″ or 10″ Schmidt-Cassegrain can do for your observing program. See the telescopes that combine the finest, most integrated electromechanical systems, including the revolutionary Smart Drive,™ with the highest level of optical precision in the industry today.

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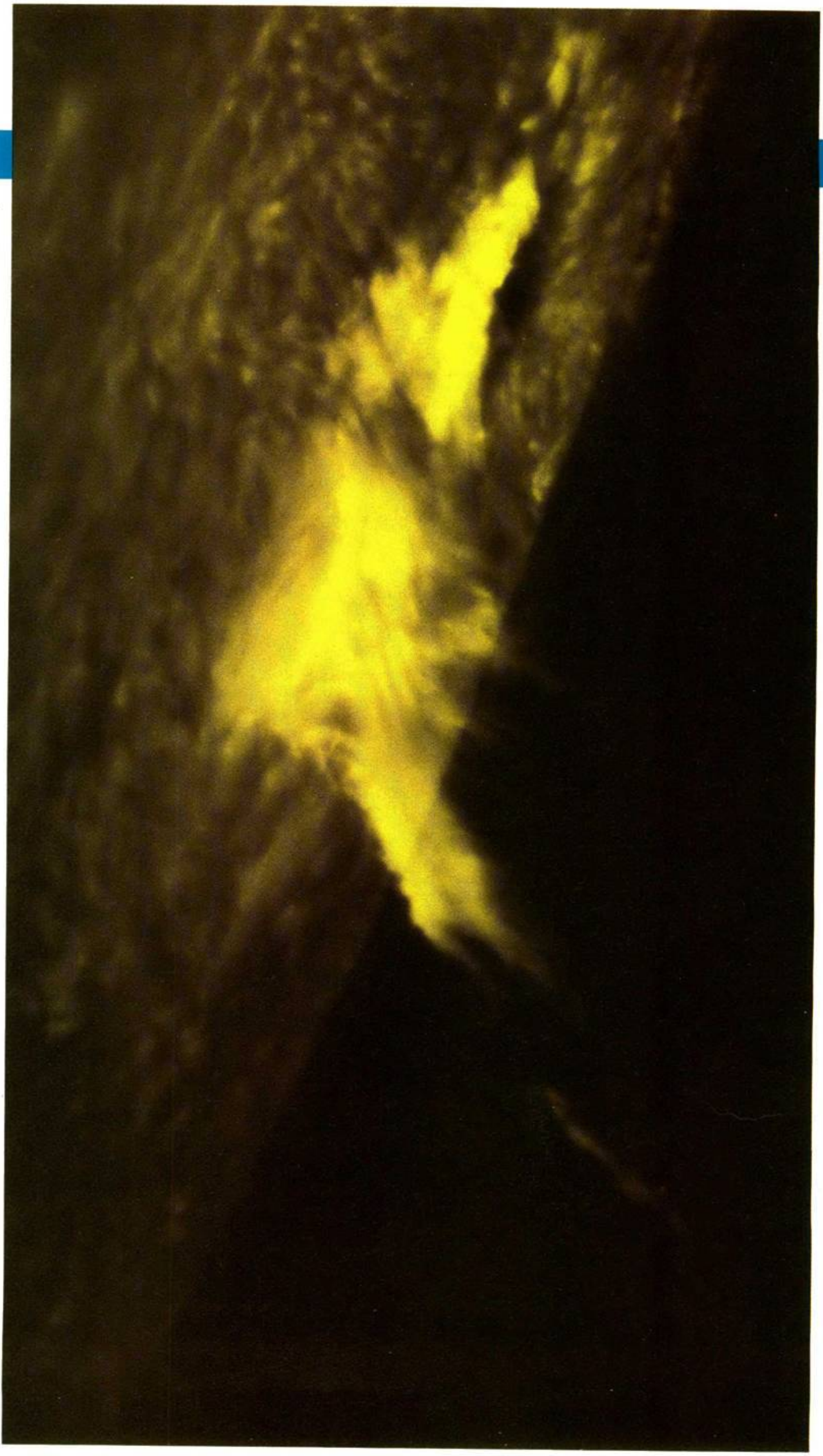
ON THE COVER: Amateur astronomer Jack Newton combined three 2-minute exposures made with an SBIG ST6 CCD camera into a color picture of M27, the Dumbbell Nebula. For a complete story, see page 68.



SOLAR FLARES OFTEN EJECT GAS to produce surge prominences like this one. To learn how to observe flares of our nearest star, see the story on page 74. H-alpha photo courtesy National Solar Observatory/Sacramento Peak.

ASTRONOMY®

February 1992

Vol. 20, No. 2

30 Will Supernova 1987A Shine Again?
The brightest supernova of the last 400 years has faded from sight, but for how long? By Laurence A. Marschall and Kenneth Brecher.

38 NASA's Never-Ending Mission
Some of the greatest discoveries of the space program have yet to be extracted from mountains of data stored on Earth. By John Williams.

44 Shedding Light on Dark Matter
The fate of the universe is controlled by matter impossible to see and difficult to find. By Richard Monda.

52 Galileo Views Gaspra
Last October, Galileo gave us our first close-up look at an asteroid. By Richard Talcott.

58 ASTRONOMY Sky Almanac

68 Celestial Seeing: Three Imaging Technologies
Amateurs now have three great ways to capture the sky. By Richard Berry.

74 Flares!
Here's how to beat the odds and see rare outbursts on the Sun. By Richard E. Hill.

80 A Personal and Permanent Journey through the Universe
Enjoy a great night of observing even years later. By Gregory L. Zentz.

83 Moonlighting
Capture stunning deep-sky photos with the Moon in the sky. By Robert Reeves.

Departments

6 Behind the Scenes
6 Letters
14 Viewpoints
Astronomy for Adults
20 AstroNews
Comets and the Origins of Life
24 Amateur News
Solar System Finds Home
26 Space News
Pioneer Venus: Good to the Last Drop
89 Reader Reports
A Peak Experience at Mauna Kea
94 Astronomy Books
98 AstroBytes
Voyager for the Amiga
104 New Astronomy Products
108 Meetings and Events
112 Readings and Resources
112 Credits
114 Advertiser Index

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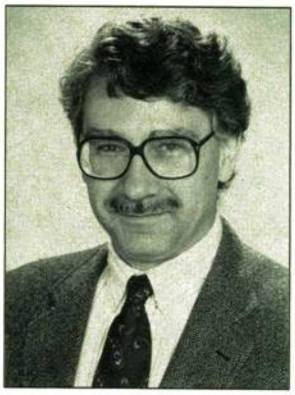
The Audit Bureau

Behind the Scenes

A NEW ADVENTURE



When I joined the staff of ASTRONOMY sixteen years ago, I embarked on a great adventure. Back then, ASTRONOMY was a tiny magazine. The entire editorial staff worked together in a single office remodeled from an old beauty parlor. We typed our stories on terrible manual typewriters and pasted up pages with hot sticky wax. It was a tacky, primitive environment, and I loved it.

But change came rapidly. Six months after I joined ASTRONOMY's staff, the magazine's inspiration and founder, Steven Walther, was told he had a brain tumor. Steve survived less than a year after surgery. I still remember one of the last times I saw him: he fixed me square in the eye and asked, "You'll take care of my magazine, won't you?" I promised I would.

Today ASTRONOMY is without doubt the leading astronomical magazine in the world, and I am proud of my role in putting it there. For over 160,000 readers, ASTRONOMY combines the primitive thrill of discovering our universe with the intellectual pleasure of understanding it. Steve Walther would not be simply happy — he'd be ecstatic with ASTRONOMY.

But the time has come for me to begin another great adventure, this time my own, and to follow my instincts wherever they may lead. Although I am sad to be leaving ASTRONOMY magazine, I most assuredly intend to remain active in the field of astronomy. This year I'm speaking at the Winter Star Party, and I'll probably meet some of you ASTRONOMY and *Telescope Making* readers at the Texas Star Party, the Riverside Telescope Makers Conference, Stellafane, and AstroFest.

I expect to continue writing for ASTRONOMY and possibly for our sister publication EARTH, and I even want to complete several railroad stories that I never had time to finish for *Trains* magazine. In the near future, I will be working on a book about CCDs that complements my latest book-and-software production, *Astronomical Image Processing*, and I've got several proposals in the Kalmbach book pipeline. Altogether, I expect to remain both busy and productive.

In closing, I want to thank all of you loyal ASTRONOMY readers for the wonderful adventure you've given me. Because of you, it has been a pleasure to edit ASTRONOMY. As I look forward now, I'm sure that we will meet again.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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Publisher's Note

As he tells you in Behind the Scenes, Richard Berry is leaving ASTRONOMY. We will miss him and his dedication to both the science and the hobby. Richard has a rare talent for making complex scientific information understandable and entertaining. He has succeeded in the difficult task of taking care of Steve Walther's fledgling magazine; moreover, under his leadership, ASTRONOMY has become an internationally known and respected science publication.

Richard is leaving ASTRONOMY well prepared for the future. The magazine is fortunate to have a strong, dedicated staff of editors who will continue the work he began. They and Kalmbach Publishing Co. are committed to bringing readers the best astronomy magazine possible.

Richard, we wish you great success in all your endeavors.

Robert A. Maas

Robert A. Maas
Publisher

Letters

Teach Astronomy in School

Astronomy is difficult to pursue as a teenager. My friends don't understand my fascination with the universe and my parents think it is unduly expensive. But astronomy isn't covered in my high school, so I must learn it on my own. It bothers me that our teachers and schools don't take astronomy more seriously because most of my generation is ignorant about the subject and science in general. Science is important for our future, but how can we learn about it when subjects like astronomy are not taught in school?

Astronomy is still an independent undertaking for teenagers. If there are other teens out there reading this, keep it up! You're the future of astronomy.
— *Niki Martin, Kansas City, Missouri*

Harriet Witt Miller makes some compelling arguments in her Viewpoints article (October 1991 issue). After reading the article, I thought back to childhood days when I looked up to the

Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

- George N. Storm, California

Photo by Jim Riffle

Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  1) Apo-refractor - basic design
  2) Tele Vue reputation
  3) Dealer owns same model
  U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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heavens and yearned to know more about them. I was frustrated because astronomy instruction was almost nonexistent at my elementary and secondary schools.

It was a miracle that in my case the frustration didn't lead to a lack of interest as it has for thousands of youths. Miller speaks of using astronomy to broaden public perspectives. But why not teach it to children whose perspectives are still forming?

The lack of astronomy education in elementary and secondary schools is distressing, and it may be no coincidence that student performance in science is low in this country. Are there any organizations that actively pursue astronomy education at these levels? *— Gary Lai, Binghamton, New York*

— Many amateur and professional astronomers donate time to present programs in local schools and find the experience richly rewarding. Schools need more of us to contribute in this way, so interested readers should contact local schools and volunteer. Also, the Astronomical Society of the Pacific and the American Astronomical Society jointly produce a newsletter on teaching astronomy for teachers of grades 3-12. Encourage teachers at your local school to request a free copy on school stationery from the Astronomical Society of the Pacific, Teacher's Newsletter, 390 Ashton Avenue, San Franscisco, California 94112.

Using Your First Telescope

I have only one complaint about "How to Buy Your First Telescope," the special pullout section in the November 1991 issue. In my opinion, your answer to question 20, "Can I use setting circles to find things?," lets observers off the hook too easily. I believe that accurate polar alignment is necessary. Once you have learned how to align your scope, you have a powerful tool for locating deep-sky objects at night and bright stars and planets during the day. Thanks to good alignment, I observed Venus at inferior conjunction on August 22, 1991.

Polar aligning your scope is easy! Polaris will help you point the scope north. You need not bother with the right ascension circle. If you know the object's declination and have aligned your scope properly, the object should be in your finder on the first or second sweep. Once you learn how to align your scope, you will never want to observe with an unaligned scope again. *— Herman Heyn, Baltimore, Maryland*

— Setting circles can be useful, provided the telescope is accurately aligned to the celestial pole and the declination circle is properly set. The circle should read 90° when the scope is aimed at 90° declination. As Mr. Heyn suggests, observers who take these steps can find setting circles useful. But in our experience, many beginners have trouble with setting circles and have better luck using star-hopping to find deep-sky objects.

Farthest Galaxies?

I read with interest in the October issue the news report on the deepest view of the universe. It states that the galaxies in the image obtained with the New Technology Telescope might lie at distances of 18 billion light-years, or even farther. What is the evidence for such large distances? *— Elmer Tucker, St. George, Utah*

— The faintest galaxy in the image appeared at magnitude 29.1. A dwarf elliptical galaxy one million light-years from our Galaxy would appear at magnitude 9.5. If the NTT galaxy is also a dwarf elliptical, we can compare its brightness to the brightness of the galaxy at one million light-years to determine how much farther away the NTT galaxy lies. There is a 19.6 magnitude difference between the brightnesses of the two galaxies, so the NTT galaxy appears 69 million times fainter. Since light becomes fainter as the square of the distance to an object, the NTT galaxy must be 8,300 times farther away than the dwarf elliptical. So if the NTT galaxy is also a dwarf elliptical, it must be at a distance of 8.3 billion light-years.

But if the NTT galaxy is a normal spiral galaxy, it is larger and much more luminous than the dwarf elliptical galaxy in the example above. Being more luminous, it would lie at a greater distance — 18 billion light-years — than the dwarf elliptical in order to have the same apparent magnitude. If the NTT galaxy is larger and brighter than a normal spiral galaxy, it would be even farther away than 18 billion light-years.

A New Binary Star Discovered

On September 15, 1991, Robert J. Wood, Sean Sullivan, and I traveled to a place just south of Jacksonville, Florida, to observe a grazing occultation. The blue, 6.0-magnitude star occulted by the Moon is known as HD 158704 (also SAO 185474 and HR 6520).

When the star blinked out at my station, I noticed that it was a sluggish rather than sharp disappearance. When the star was in deep occultation, I saw a very faint secondary star. I estimated this star to be about magnitude 8.6.

After we measured our positions, we called David Dunham of the International Occultation Timing Association. He confirmed that the star was a previously unknown binary. From 28 timings, we were able to compute that the separation of the stars is several tenths of an arcsecond. *— Harold Povenmire, Central Area Graze Observers, Indian Harbour Beach, Florida*

A South African Astronomer

As a child, I followed the constellations with my naked eye and knew most of them well. Unfortunately, with the passage of time, along with marriage, children, and career, I abandoned the hobby. I have resumed this fascinating pastime upon my retirement. I now observe with 7x50 binoculars and find that the peace and tranquillity of the evening sky is even more fascinating than before.

I had to learn the constellations all over again, this time from the Southern Hemisphere, having emigrated from Scotland to South Africa. Soon, I will be the proud owner of an 8-inch telescope that will enable me to see more of the glorious sights beyond the reach of my binoculars. Thank you for the Southern Sky insert each month, which is invaluable to us Southern Hemisphere observers. *— Mrs. D.M. Robertson, Atlasville, South Africa*

Terraforming the Moon

In his article "Glorious Universe" (October 1991 issue), Robert Burnham suggests that the Moon might become habitable through the introduction of an atmosphere and hydrosphere. Given that the Moon's gravity is roughly one-sixth of Earth's, it seems to me that elements such as oxygen and nitrogen would rapidly escape into space. *— Kevin Starnes, Denver, Colorado*

— Half of a newly created atmosphere on the Moon would escape in roughly 14 years. So the people terraforming the Moon would have to either enclose large tracts of the lunar surface so as to maintain the atmosphere or continually replenish the atmosphere somehow. □

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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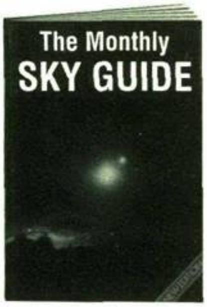
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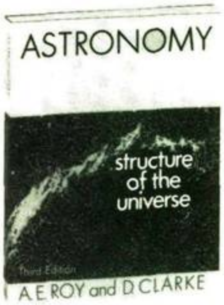
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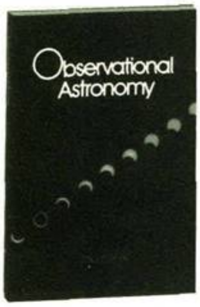
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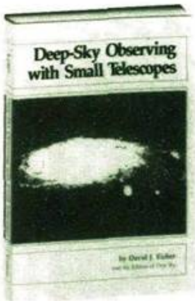
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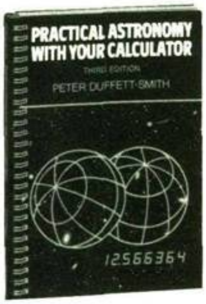
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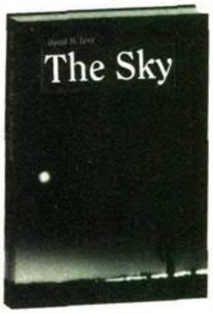

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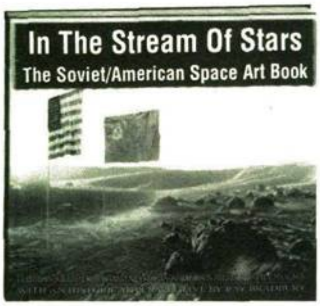
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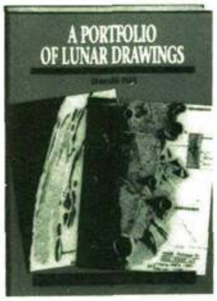
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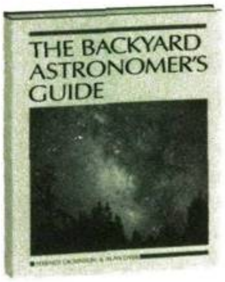
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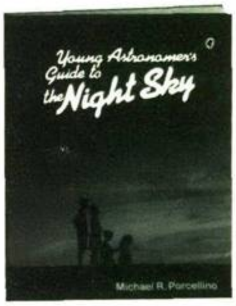
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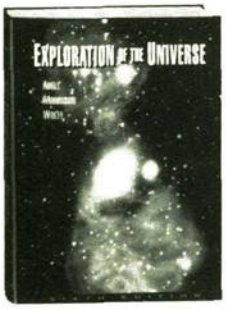
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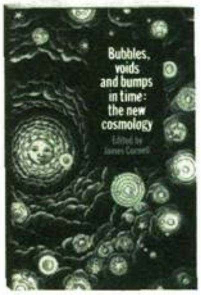
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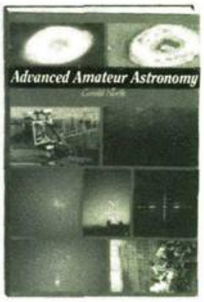
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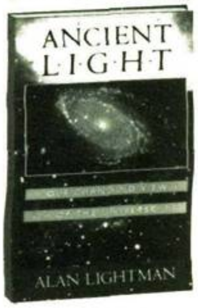
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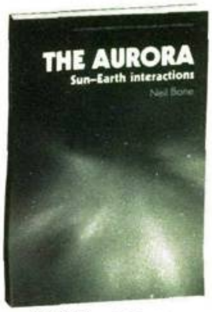
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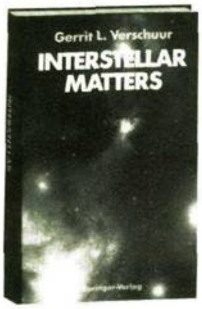
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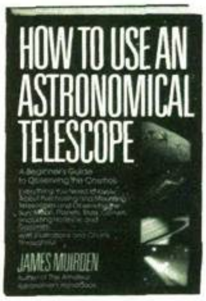
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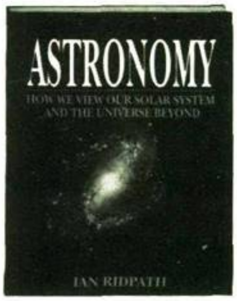
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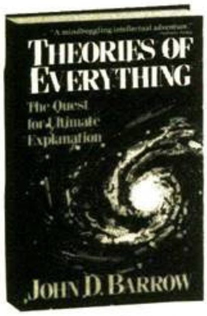
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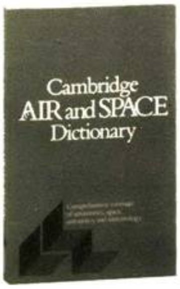
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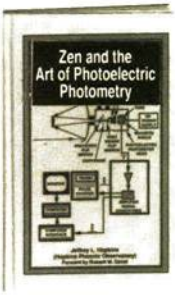
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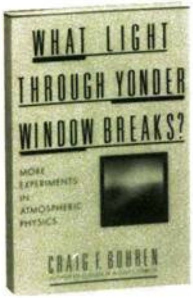
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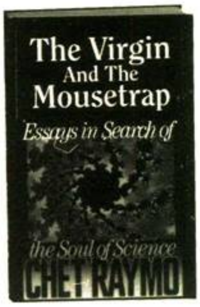
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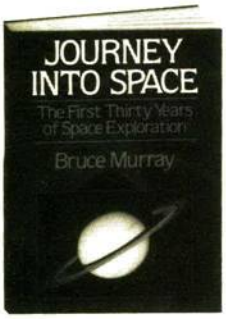
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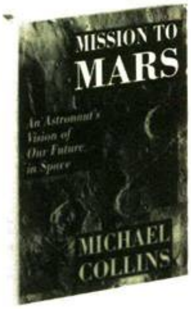
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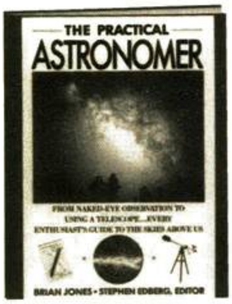
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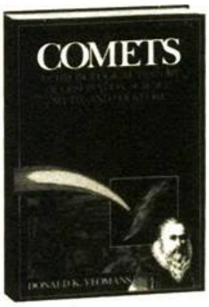
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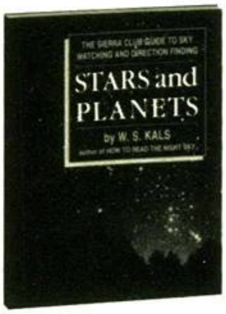
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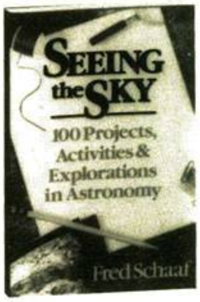
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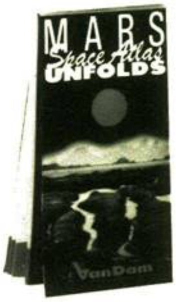
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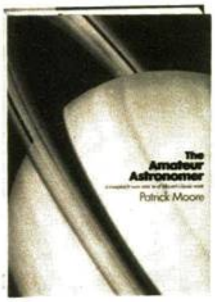
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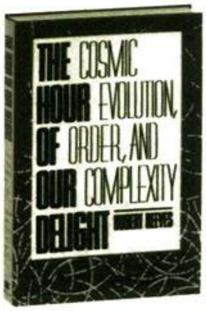
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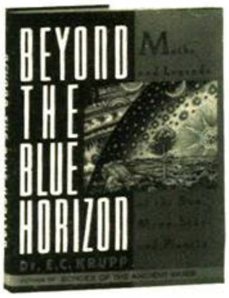
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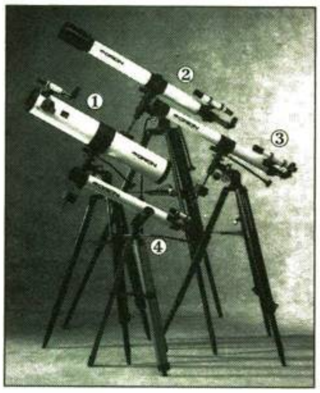

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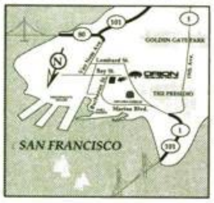

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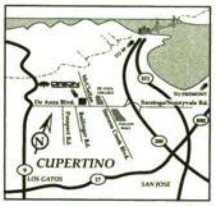

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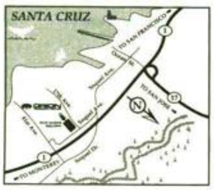

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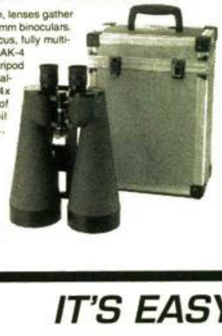

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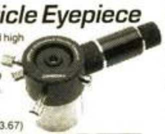

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ASTRONOMY FOR ADULTS

by Geoff McNamara

At a recent session of my evening college astronomy course, I had my students build a model of the Local Group of galaxies. They cleared the coffee mugs from the table and placed cardboard cut-out models of the Milky Way Galaxy, M31, and dwarf ellipticals in the center.

Next they labelled pieces of paper with right ascension (RA) coordinates and placed them around the edge of the table at six-hour intervals. They cut the galaxy models to the same scale used for distance and used the RA and distance information for each galaxy to position the models correctly on the table. After ten minutes, they had built a two-dimensional model that showed how the Local Group is arranged.

I can almost guarantee that all of these students have forgotten the galaxies' distances and directions. Few probably remember the diameters of the Milky Way Galaxy and M31. But ask them to sketch the relative distance and sizes of the two spiral galaxies and they would produce a reasonable rendition. They didn't learn the relative sizes of the Local Group by hearing numbers or even seeing a drawing of the galaxies. They learned by doing!

Such beginners sessions have run in Sydney, Australia, for nearly two years. At the end of the first course, the students asked for a second course. Apparently even two eight-week courses weren't enough, because I now offer six courses. Most students stay for at least three courses, while two students have completed all six courses.

What makes a successful astronomy course is recognizing the needs and background of the people attending. For most evening courses, the attendees are older than the average college student. They come from all sorts of backgrounds: plastering, metallurgy, bookkeeping, and retirement. Some have a longstanding, if mild, interest in astronomy. Others signed up for the course on a whim.

No matter what their background, these students share two common traits. They typically come from a long day's work, so the last thing they need is a lecture that will probably put them in a zombielike state. Secondly, most do not have a science background. Sure, astronomy is a science and should be described as such. But if the instructor uses only numbers and scientific terms, the average student will just sit there and stare around the room out of boredom.

Moreover, humans learn about the world around them using five senses. Three can be used effectively when teaching astronomy. (I'm still thinking about how smell and taste could be used.) Most people get bored with teaching methods that use only one sense.

When teaching an astronomical concept, I use models whenever possible. The Local Group model — and a similar exercise building a three-dimensional model of Crux, the Southern Cross — uses three senses. The students *hear* me describe the Local Group. Then they *read* some relevant information. Following this, they pick up and *feel* the galaxy models. Finally, they stand back and look at the model from a variety of angles.

Adults spend many years taking in information and processing it themselves. One path to learning for them is their experience. Giving them small yet sufficient amounts of information allows my students to discover the nature of a concept but requires that I think carefully about how students can learn each concept through activities.

I also like to incorporate what I call the human element. Adults appear to relate more to astronomy when they see both their emotional and intellectual side. When conducting a session on pulsars, for example, I wrote some quotes on pieces of paper. One of the women attending the course played the role of S. Jocelyn Bell Burnell and *proceeded to* describe to us the events leading up to the discovery of pulsars. Every now and then we paused in the monologue to permit discussion about what the Cambridge team was doing at the time. Thanks to several humorous remarks spoken byBurnell and quoted by the student, the discussion also was entertaining.

Another technique I use is well known to teachers at all levels. I draw information from students by asking them leading questions. But when the students don't know much about the subject, how do you ask them questions about it?

The technique I use is to draw on unrelated knowledge or experiences they already have. For example, when developing concepts about the formation of the solar system, I first provide some basic facts. These include such information as the nature and composition of a molecular cloud and the idea

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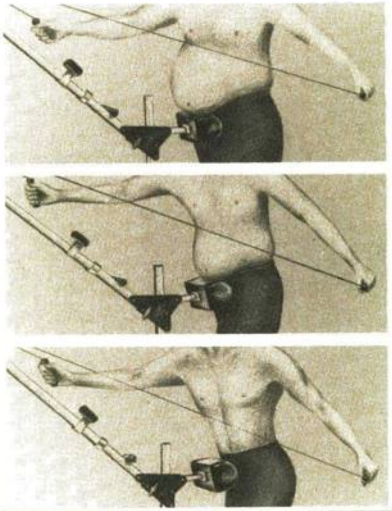

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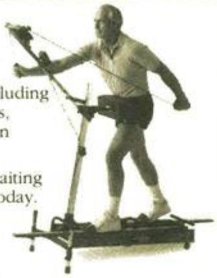

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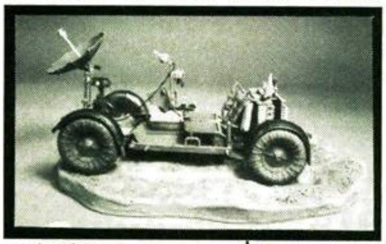

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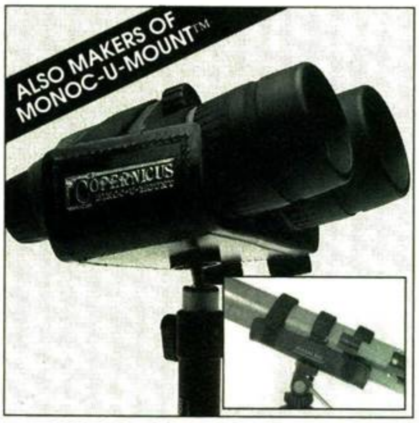

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that everything in space is drawn together by gravity. "What will happen to this cloud?" I ask. Responses at first might be slow in coming. After all, few students like to sound foolish in front of strangers.

Eventually someone will say that the particles will start to come together. "Where are they being drawn to?" "The center of the cloud." "What is it like in the center of the cloud?" "It's getting denser." I continue gently drawing on the students' knowledge and experience. They soon build for themselves the concepts regarding the formation of the Sun, the planets, and comets.

Every now and then someone asks a question that at first seems ridiculous to us because we as instructors know something about astronomy. A recent example occurred in my class when we were talking about the Sun. We concluded that the Sun was made of gas and discussed similarities between the Sun and the gas giant planets. One student had read that the gas giants have a rocky core and asked why the Sun doesn't have a rocky core. If I had scoffed at his question, the student not only would have felt stupid, but might not have appeared at the next class. His interest in astronomy might have been crushed along with his ego.

How does the instructor answer such a question? I don't. I let the student answer it. I asked him to recall what he knew about the temperature and pressure inside the Sun. "Could anything remain as a solid under such conditions?" He answered his question himself. He not only learned something, but reasoned it out for himself. Ego intact, a little more learned, and his reasoning skills further developed.

Teaching is the most rewarding and stimulating activity I've ever undertaken, and I encourage you to try it. I feel good knowing that I've helped someone else learn about astronomy and develop their thinking skills. Plus, I enjoy sharing my love for astronomy with others. With each class, I feel another battle has been won against scientific illiteracy, people have grown and learned a little more, and every now and then a new amateur astronomer is born.

HOW TO INSPIRE ASTRONOMY STUDENTS

by Hal Jandorf

Most students who take introductory astronomy in college signed up for the course to fulfill their science requirement for graduation. Astronomy appears a more palatable course for non-scientists when students look at the other choices: physics, chemistry, and biology. And astronomy seems like it will be fun, full of mystery and romance. But first of all, from the students' point of view, astronomy is less intimidating than its sister sciences, especially if the students had little science in high school. The students expect an enjoyable and understandable course. And an easy grade.

After several months, students often discover that they are saturated with complex formulae, theories, and facts they can't relate to the practical world. Many end up disliking science and astronomy and writing off the course. A class that started with eighty students drops in enrollment to twenty-five.

Unfortunately, too many introductory astronomy courses have the same format and cater to the science-minded student. In reality, the overwhelming majority of students who take introductory astronomy will never become professional astronomers or scientists. Most of the students are taking a college science course for the first — and probably last — time. Why do so many beginning astronomy courses disappoint the thousands of students enrolled each semester? Perhaps it has to do with the teacher.

As instructors, we need to live up to the student's expectations, be patient with the students' scientific shortcomings, and teach a lively course. If we confuse them with irrelevant facts, they will never understand any of it. The first taste of college science has to be good. Otherwise, the students will be turned-off by astronomy — and science in general — forever.

Science funding and scientific illiteracy are important public issues today. More science classes should be taught in our public schools. But how can we convince the public that science is important and that it should be publicly funded when science courses do not meet their needs?

Instructors should take a good look at the students taking introductory astronomy: a liberal arts student shying away from math, a college drop-out trying to tackle the science requirement that she or he evaded years before, a person looking for help in buying a telescope and hoping astronomy will become a lifelong hobby, students looking for a challenging major, a couple eager to share the challenge

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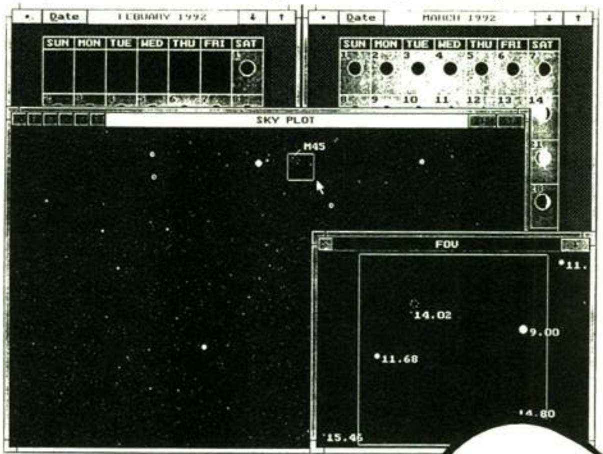

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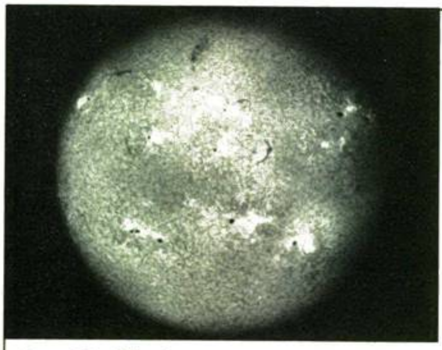

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of astronomy, and elementary school teachers looking for hints to help teach their students about the solar system.

These students are not the minority. Some have never learned the constellations or causes of the Earth's seasons or the Moon's phases. They don't know the difference between astronomy and astrology, comets and meteors, stars and planets. They've never looked through a telescope — but they'd love to! They need basic astronomy before they learn about astrophysics.

To preserve the spark in astronomy, we need practical astronomy in introductory courses. For students, amateur astronomy brings the cosmos into the real world. What makes astronomy inspiring to them are a view of the Milky Way in an inky sky, a first glimpse of Saturn or Jupiter's moons through a telescope, and the deciphering of those connect-the-dot patterns we call constellations. These involve students personally in astronomy, priming them for learning about science.

When discussing stellar properties and evolution, we need to show slides of constellations and comment on the stars' colors and brightnesses. We could accompany lectures on the Milky Way Galaxy and cosmology with slides of gaseous nebulae and galaxies. Slides taken by amateurs sometimes make a bigger impression than those taken at professional observatories, because students can identify more with the amateur's equipment.

We should mention binocular observing, as well as events like meteor showers, occultations and lunar eclipses. If the class meets during the day, we might assign homework involving naked-eye observing of the phases of the Moon, constellations, star colors, and planet motions. Night classes could set up a telescope for observing. In class we might talk about amateur telescopes as well as the professional instruments at Palomar and Mauna Kea.

Most importantly, we should invite the students to star parties so they appreciate the real universe outside the classroom and textbooks. The students expect to observe so don't let them down! Join the local astronomy club during star parties at least once a month so the students can compare the view through several instruments.

Teaching astronomy should be a passion that will infect the students with enthusiasm for the course. And who knows, for some it may be the beginning of a love affair with the stars. ☐

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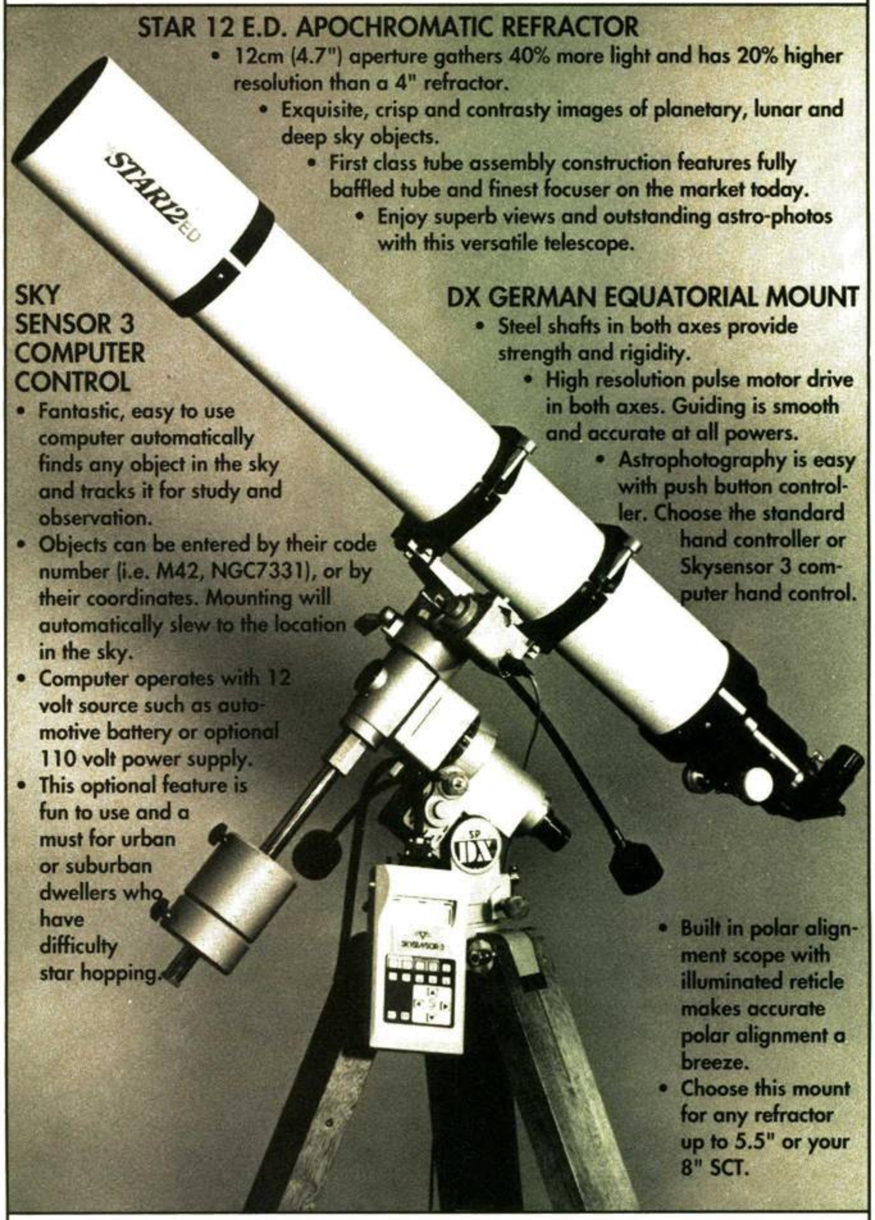

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COMETS AND THE ORIGINS OF LIFE

"Comets may be the bringers of life." Last October Carl Sagan of Cornell University described what a growing number of scientists believe triggered life on the early Earth: comets and interplanetary dust particles.

No one disputes that comets contain abundant organic molecules. The arguments in this burgeoning field now center on whether life — self-replicating organic molecules — began in the particles of comets and were deposited on Earth; whether cometary particles planted the seeds that resulted in life on Earth; or whether comets played little or no role in the formation of life despite their abundance of organic molecules.

It's a tricky set of questions to answer, and scientists are sometimes as stymied by what constitutes an exact definition of life as they are by an array of other disputes.

From September 30 to October 2, astrophysicists, cosmogonists, and organic chemists met at the University of Wisconsin at Eau Claire to share their latest findings. "It comes down to a matter of exogenous vs. endogenous," says Sagan. "In other words, life originating externally or with external help, or originating on Earth without external influence." Scientists know that life originated prior to 3.8 billion years ago, during the "heavy bombardment" phase of Earth's history, when numerous massive cometary nuclei slammed into Earth. They know that organic molecules exist within cometary particles, including such compounds as carbon dioxide and hydrogen cyanide. Scientists also know through relatively simple tests that, given energy (sunlight, heat from the Sun), such organic molecules will break apart and recombine into more and more complex polymers. This process leads to the formation of amino acids, which transform into proteins to make deoxyribonucleic acid (DNA), the building block molecule of living beings.

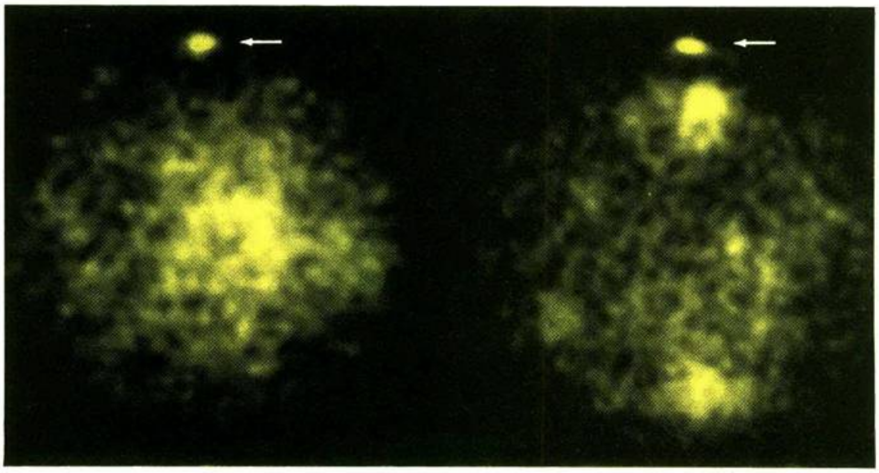
So the circumstantial evidence that comets played a large part in depositing organic molecules on the early Earth is strong. "We know that impacts of less than about 9 kilometers per second involve temperatures low enough so that some organics could survive," says Chris Chyba, a colleague of Sagan's.

Chyba details three more mechanisms for getting intact organic molecules deposited on Earth's surface: airborne impact, where comets collide with the atmosphere and their debris gently rains down; interplanetary dust particles, which fall to Earth slowly and in great quantity; and shock energy from heavy impacts that creates organic molecules on the surface of Earth.

Some scientists go farther in their interpretation of comets. "Not only organics, but Earth's water could have been brought in by comets," says Armand H. Delsemme of the University of Toledo.

Despite the strong circumstantial evidence, the scientists do not know the answer in an absolute sense. Some highly respected scientists are downright hostile to the comets-and-life connection. For example, Stanley L. Miller of the University of California at San Diego is an outspoken opponent and has unique expertise in the field. In the early 1950s Miller teamed up with Harold C. Urey to create the first "spark-chamber" experiment showing that complex organics could form from a primordial soup of hydrocarbons. And now, largely due to differences over how much electrical energy existed in Earth's early atmosphere and the survivability of amino acids in Earth's oceans, Miller presented a paper with the confident title, "Comets and meteorites were not a significant source of organic compounds on the primitive Earth."

The field is likely to spur lively debate for some years to come, at least until many dozens of research projects show more about the early Earth and spacecraft like CRAF and Rosetta shed more light on comets. A long path lies ahead, according to Sagan: "Until we understand the atmosphere of the early Earth, particularly how much of a neutral or reducing atmosphere Earth had at various times in its early history, we will not be able to solve the dilemma of exogenous vs. endogenous."



A STRONG RADAR ECHO comes back from Mercury's north polar region (arrows) in these two views of the planet made on August 8 and 23, 1991. The other radar echoes come from regions of broken rock, thought by scientists to be large craters and impact basins. Caltech/JPL images.

DOES MERCURY HAVE POLAR ICE DEPOSITS?

A group of astronomers at the California Institute of Technology has made the first radar photographs of Mercury. The photos show a strong echo coming from the planet's north polar region. The scientists — Duane Muhleman, Martin Slade, and Bryan Butler — interpret this radar return, at least provisionally, as being due to water ice. The result is a surprise because most planetary scientists have assumed that Mercury was far too hot to have ice deposits.

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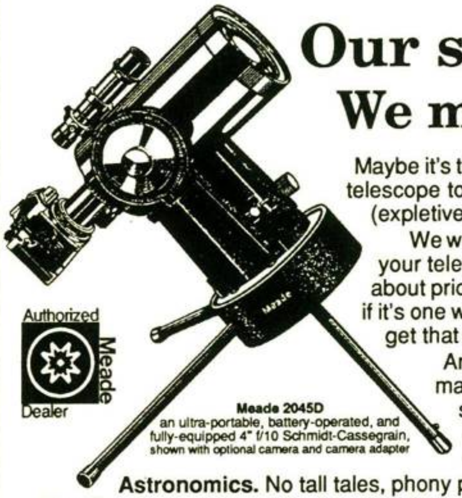

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receiver. The geometry of the two planets during the experiment tipped Mercury's north pole about 12° toward Earth, thus permitting the antenna to "see" the region more clearly.

Planetary scientists think the polar regions of Mercury could have deep craters whose interiors are shadowed frequently or even permanently. This happens because Mercury's axis stands at 90° to its orbit and the planet experiences no seasons. According to calculations by UCLA astronomers David Paige and Stephen Wood, the shadowed polar regions on Mercury could be at a temperature of 125 kelvins — cold enough to freeze out many substances, including water.

But where would the water come from? The source is unknown, but the Caltech astronomers point out that from time to time Mercury will be struck by comets, which are largely made of water ice. The impact would destroy the comet and give Mercury a transient water vapor atmosphere. Before the powerful sunlight drove off all the vapor, however, some of it could condense in the cold polar regions.

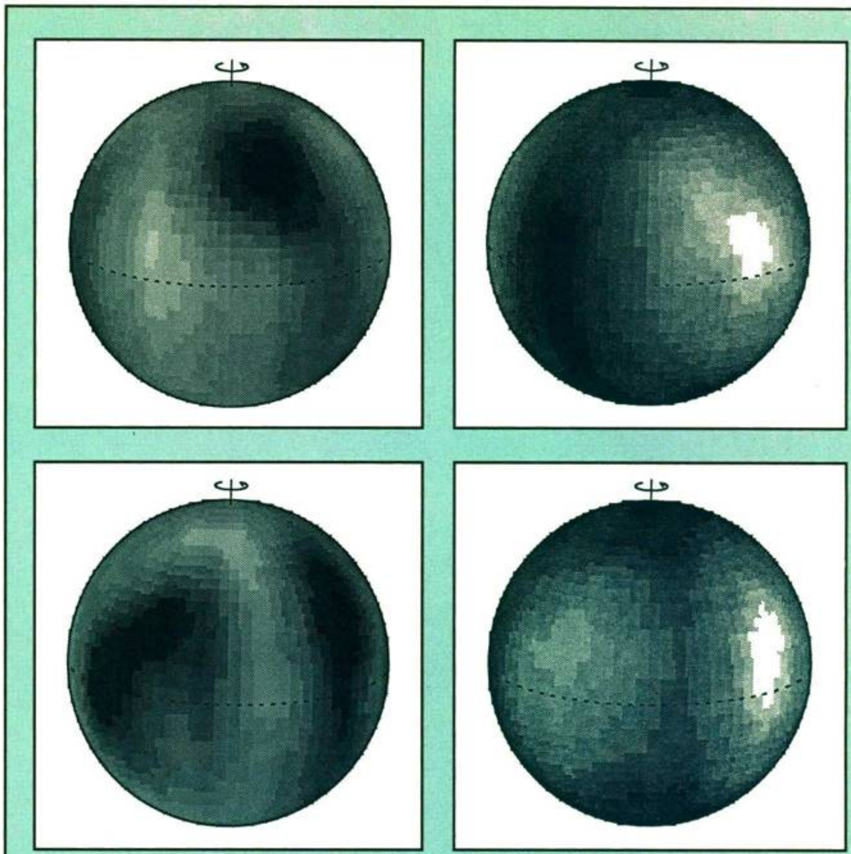
A BRILLIANT GAMMA-RAY QUASAR

Quasars are famous for being extremely energetic. In fact, as a class they are the most luminous objects in the universe, emitting copious amounts of radio, infrared, optical, ultraviolet, and X-ray radiation. (See "The Emerging Picture of Quasars" in the December 1991 issue.)

But what about gamma rays? Only one quasar, 3C 273, had ever been seen in gamma rays before and it happened to be the brightest quasar in optical light as well. With the launch last year of the Gamma Ray Observatory, astronomers hoped to learn whether other quasars were also intense sources of gamma rays.

The wait is over. Late last summer, investigators on the observatory's Energetic Gamma Ray Experiment Telescope discovered the most luminous source of gamma rays in the sky, and it turned out to be the quasar 3C 279. The pointlike source, located about 7 billion light-years from Earth in the constellation Virgo, emits some 10 million times more energy than the Milky Way Galaxy.

The GRO observations also hint that 3C 279's output of gamma rays varies significantly. Previous gamma-ray observatories should have seen the quasar quite easily, assuming it was as bright then as it is now. That 3C 279's gamma-ray emission remained undetected till now shows that quasar luminosities vary across the entire electromagnetic spectrum.



ASTRONOMERS CAN NOW MAP MAGNETIC FIELDS on stars like HD 82558, a K-type dwarf that shows hydrogen emission. Steve Saar of the Center for Astrophysics and Nicolai Piskunov of the University of Helsinki used the broadening and strengths of several spectral lines to determine magnetic field strength (both images at right) and temperature (images at left) across the star's surface. The top images show one side of the star while the bottom images show the other side. The dark "spots" are near, but not coincident with, the strongest magnetic fields, suggesting that the strong fields are related to features like the Sun's plage regions.

HEAR "EARTH AND SKY" ON THE RADIO

A new science show of interest to ASTRONOMY readers premiered September 30 on commercial and public radio stations around the United States. Called Earth and Sky, the daily 2-minute program is the creation of two leading staff members of the long-running Star Date radio show. Deborah Byrd, who created Star Date in 1977, and Joel Block, the voice of Star Date, are producing the new Earth and Sky series in association with the American Geophysical Union based in Washington, D.C.

Byrd, known to ASTRONOMY readers as writer of this magazine's monthly Eye on the Sky department, left Star Date after a dispute with management at the University of Texas McDonald Observatory. Byrd explained, "Star Date was going strong, and I didn't intend to leave it, but now that I have, I'm excited about the opportunity to create a brand new program." Block added that the new show "will still transport listeners out into the heavens, but in addition we'll focus some attention right here at home."

Meanwhile, the popular Star Date program airs daily on a long list of commercial and public radio stations, with science writer and Damond Benningfield serving as the program's new writer/producer.

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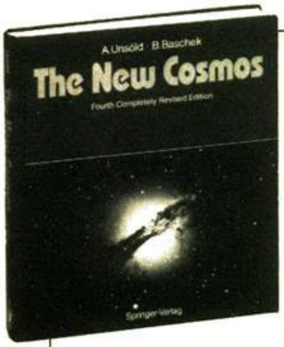

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EIGHT-METER TELESCOPE PROJECT ADVANCES

The Japan National Large Telescope moved closer to reality in early August when Mitsubishi Electric Corporation selected Corning Incorporated to manufacture the telescope's huge mirror. The mirror, which will measure 8.31 meters in diameter (327 inches), will be the largest monolithic mirror in the world and allow astronomers to explore cosmic mysteries in the depths of space.

Corning, who provided the mirror blank for the 5-meter Hale telescope in 1937, will make the mirror blank out of their ultra-low expansion glass. This glass keeps its shape when the temperature changes, providing high-quality images throughout the night. The blank will consist of many hexagonal-shaped pieces fused together to form one large, monolithic blank. When complete, the blank will measure just 8 inches thick and weigh in at a hefty 60,000 pounds.

It will take Corning three years to manufacture the mirror blank and an optical finisher another three years to finish and polish the mirror. The eye of the Japan National Large Telescope will then be shipped to the summit of Mauna Kea, where it is expected to see first light in 1999.

NEW LIFE FOR AN OLD SCOPE

As the Keck Observatory sparks renewed interest in large ground-based telescopes, astronomers in Missouri are experiencing a boost in capabilities with one of their small telescope facilities. A state-of-the-art CCD camera recently mounted on a 16-inch telescope at the Baker Observatory in Springfield, Missouri, marked the rebirth of the small observatory.

According to George W. Wolf, a professor of physics and astronomy at Southwest Missouri State University in Springfield, the new camera makes the observatory the "leading astronomical research facility in Missouri." The camera has increased the detection capability of the 16-inch telescope by as much as 30 times, making it equivalent to a conventional 100-inch telescope.

Charles Peterson, a physics and astronomy professor at the University of Missouri, says the camera puts the observatory in the big leagues. "In the past, we have been in the awkward situation of running an observatory with only one or two people," says Peterson. "Now these marvelous devices have come along and all of a sudden we can do projects comparable to larger observatories with larger telescopes. We're back in the game.

"This is a very favorable development not only for us but potentially for many other small observatories," Peterson adds. "We now actually have something to get students doing some real research in astronomy and it will allow more hands-on experience for graduate students. We will be studying galaxies to determine colors and magnitudes so we can help to get a scale of a galaxy's brightness. With Cepheids, we will be studying their interstellar absorption to make sure we have the proper absolute magnitudes and from that the proper distances. The research possibilities are very encouraging." — *John Williams*

SUPERNOVA LINKED TO INDIAN POTTERY

The Crab Nebula in Taurus was first seen as a supernova in July 1054. Years ago, pictographs showing a crescent Moon and a bright star near it were found in Arizona. They are presumed to have been cut by eyewitnesses, but the dating of rock carvings is almost impossible. No European account is known, but Chinese and Japanese annals record observations of the event. For centuries, these appeared to be the only records to hold up under scientific tests of verification. This recently changed when two astronomers discovered what appears to be a depiction of the supernova on a 900-year-old piece of Mimbres Indian pottery.

University of Texas Astronomy professor R. Robert Robbins and a student, Russell B. Westmoreland, made the discovery while studying plates and bowls made by Indians of the Mimbres culture of southwestern New Mexico. They were looking for relationships between the abstract images on the pottery and astronomical events. The image of a rabbit representing the Moon is a recurring theme in American Indian art. On Mimbres pottery, it is usually shown along with crescent symbols.

The 7-inch diameter bowl which Robbins and Westmoreland feel depicts the 1054 supernova was found in the ruins of the village of Galaz, New Mexico, in the 1930s. Carbon-14 dating shows that the burial site where the bowl was unearthed was abandoned in 1070. The Mimbres first used the style of abstract art represented in the bowl around 1000 and apparently stopped using it around 1130. This places the bowl in the correct time period and indicates it was crafted by a culture with good knowledge of the heavens.

The Chinese reported that the "guest star" was visible in the daylight for 23 days. During the first morning the supernova was visible, it was southeast of Zeta Tauri and about 2° below the waning crescent Moon. On the supernova bowl, a starlike object with 23 rays around its circumference is at the hind feet of a rabbit. (The Indians usually depicted a star with only 4, 5, or 6 rays.) The researchers found the number 23 represented on only one other bowl.

Robbins and Westmoreland are sure that their research has uncovered the only scientifically verifiable depiction of the supernova of 1054 made in the western hemisphere. They plan to study more examples of Mimbres objects to see if they can definitively solve the puzzle of the Indian pottery. — *Robert A. Garfinkle*

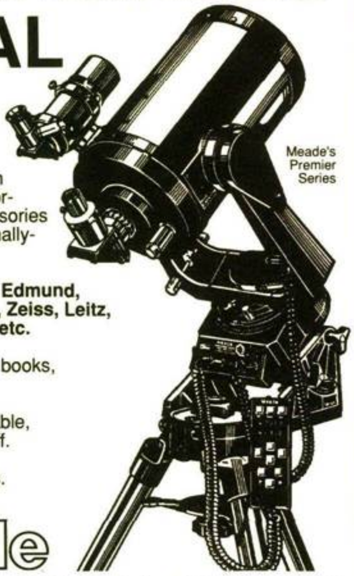
Amateur News

SOLAR SYSTEM FINDS HOME IN IDAHO

On a chilly afternoon last winter, four strong men and a boy carried a heavy wooden post through the Boise River greenbelt that passes through the heart of Boise, Idaho. They found a hole dug by the side of the bike path, set the post in, and tamped it firmly into place.

"That's Pluto," said Al Bond, "the last one."

Bond and other members of the Boise Astronomical Society (BAS) were completing an outdoor model of the solar system, a joint project of the society and the Discovery Center of Idaho.



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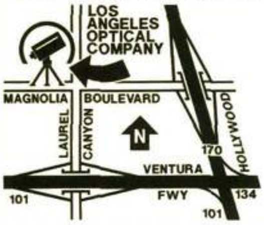

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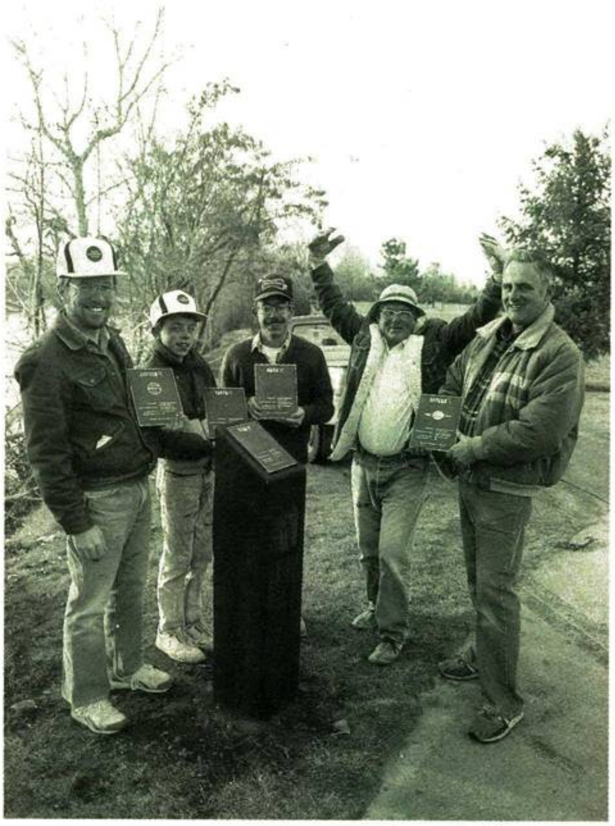
The astronomers routed the top of the post to fit a heavy brass plaque displaying a pinhead-sized Pluto along with statistics on the outermost planet. The Pluto post also directs viewers to eight other posts and a model Sun, all to scale, along a two kilometer (1.3-mile) section of the Boise greenbelt.

According to Chuck Durick, past president of the BAS, this is the first model of the solar system in the western United States built to a realistic scale for both planet sizes and distances. BAS members are aware of two other such models: one in Sweden and another along the Appalachian Trail.



The model's Sun is a half-meter-diameter powerline aerial marker ball donated by the Idaho Power Company. It will occupy a prominent position in the Discovery Center's lobby once building renovation is completed. The other planets are represented by plaques scattered through the parks forming the greenbelt. Earth, for example, is a 5-millimeter circle on a post 55 meters from the Sun. Jupiter, 284 meters away, is a 50-millimeter ellipse.

"It was surprisingly difficult to come up with the numbers. Every book we picked up had them slightly different," said Durick. The group decided to use those published in the *Astronomical Almanac*, the data source published annually by the United States Naval Observatory. Members of the BAS recognize that the planets' actual orbits are ellipses and not in the same plane, but chose average orbits to build their 1:2,750,000,000 scale model on flat ground for the sake of convenience. At that scale, the nearest visible star, Alpha Centauri, would be a basketball located at Perth, Australia.

The plaques were designed without information about specific geographic locations, allowing groups to make duplicates suitable for various locations. Other groups interested in such a project should contact the Discovery Center of Idaho, P.O. Box 192, Boise, ID 83701. — *Walt Matell.*

ASTRONOMY LAUNCHES CLUB NEWSLETTER

In November, executive officers of approximately 250 astronomy clubs received the first issue of ASTRONOMY Network News. Produced by Kalmbach Publishing and ASTRONOMY magazine, the new bimonthly newsletter is designed to provide a link among astronomy clubs around North America, especially new clubs needing advice and those that may not be part of larger organizations such as the Astronomical League or Western Amateur Astronomers. According to editor Tom Gill, "We hope that Network News will be a valuable resource for clubs and that they'll use the newsletter to share ideas and experiences."

Network News is sent free to executive officers of clubs that are on ASTRONOMY's database. Each issue will feature tips from astronomy clubs on how to meet some of the challenges faced by every club: attracting new members, organizing interesting meetings, operating an observatory, and publishing a newsletter, among others. Network News will also contain information on the free or low-cost outreach materials available to clubs from ASTRONOMY magazine.

If your club is not on our mailing list, or if you would like your club's officers to receive Network News, please contact Tammi Scherbarth toll-free at (800) 558-1544 from 8:30 a.m. to 5:00 p.m. Central Time, or write to Tammi Scherbarth, Kalmbach Publishing, P.O. Box 1612, Waukesha, WI 53187.

Space News

PIONEER VENUS: GOOD TO THE LAST DROP

NASA is a master at squeezing all the data it can get out of its spacecraft. Their Pioneer Venus (number 12 in the line) is no exception. Orbiting the second planet since 1978, the Pioneer Venus Orbiter's dozen instruments made low-resolution radar maps of the planet's surface, generated thousands of images of the clouds, and conducted close-up studies of Venus' ionosphere and magnetic field. (Also, an accompanying craft carried several atmospheric-entry probes that gathered data about Venus' atmosphere as they descended to the planet's surface.)

However, Pioneer Venus' days are numbered. Sometime between August and December 1992, the unmanned spacecraft will plunge into Venus' clouds and burn up in the atmosphere. The destruction of the spacecraft will

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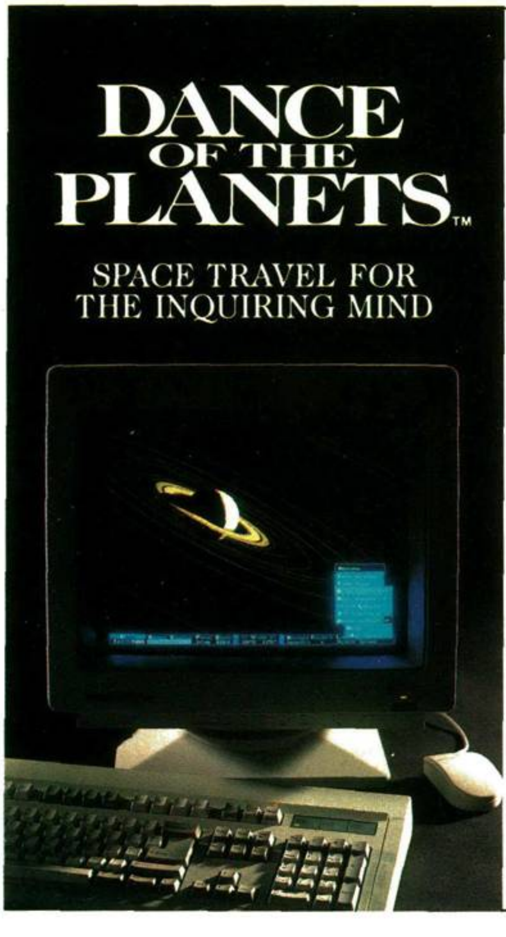

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not be without benefit, however. As the spacecraft descends into the atmosphere it will send back information that could support the Magellan program. An unmanned space probe, Magellan is currently mapping the surface of Venus with its synthetic aperture radar.

The reason behind the demise of Pioneer Venus is quite simple: it's running out of fuel. Over the years, Pioneer Venus' thrusters kept its orbit from decaying. (Onboard systems and instruments run on electricity from the craft's solar cells.) After the fuel is depleted, the craft will enter Venus' dense atmosphere and burn up. No one knows exactly when the craft will de-orbit because the spacecraft's fuel sensor is no longer providing accurate readings.

It won't be an uncontrolled descent, Fimmel explains. "We will hold it down to around a 145-150 kilometer altitude for as long as the fuel holds out. We expect to stay at that altitude for some weeks or months." Right up until the craft burns up, it will transmit information about the atmosphere to NASA scientists.

Information gathered during Pioneer Venus' final days will aid Magellan program managers in their plans to change Magellan's orbit. Currently, Magellan is in an elongated orbit with its periapsis at 290 kilometers and its apoapsis at 8,460 km. Magellan program managers would like to lower and circularize the spacecraft's orbit at about 150 km. This will improve radar imaging and gravitational experiments being conducted with the craft, according to Magellan Mission Manager, Jim Scott.

To lower the orbit will require a tricky — and hazardous — maneuver called aero-braking. This maneuver involves having the spacecraft skim through the planet's upper atmosphere. As the craft passes through the air, drag causes it to slow down. If the craft skims in at too shallow an angle, it will skip out of the atmosphere into an uncontrolled orbit. If it goes in too deeply, friction will cause it to burn up.

This is where Pioneer Venus comes in. As Pioneer Venus travels through the outer atmosphere, it will gather information about the forces that Magellan will experience during its aero-braking maneuver. Using the data gathered by Pioneer Venus, Magellan scientists can plot the best course for their spacecraft and increase the chances that it will survive the aero-braking maneuver.

Jim Scott cautions that aero-braking Magellan is still in the early planning stages and nothing has been decided. It won't be attempted until 1994 at the earliest, after Magellan has made four complete radar mapping passes over Venus. What is definite is that Pioneer Venus will terminate its 15-year career by the end of 1992. And in keeping with NASA's long-held tradition of squeezing every bit of data from its space probes, even the demise of Pioneer Venus will be useful in the continued study of the planet Venus. — *Robert G. Nichols.*

SOVIET SPACE EXHIBIT TOURS AMERICA

The Soviet space program — the very words evoke the mystique of government secrecy and international intrigue. But a new exhibit currently touring the United States is doing much to lift the cloak of secrecy. The exhibit, called "Soviet Space," consists of 80 tons of space hardware, including functioning copies of some of the Soviet craft that made space history.

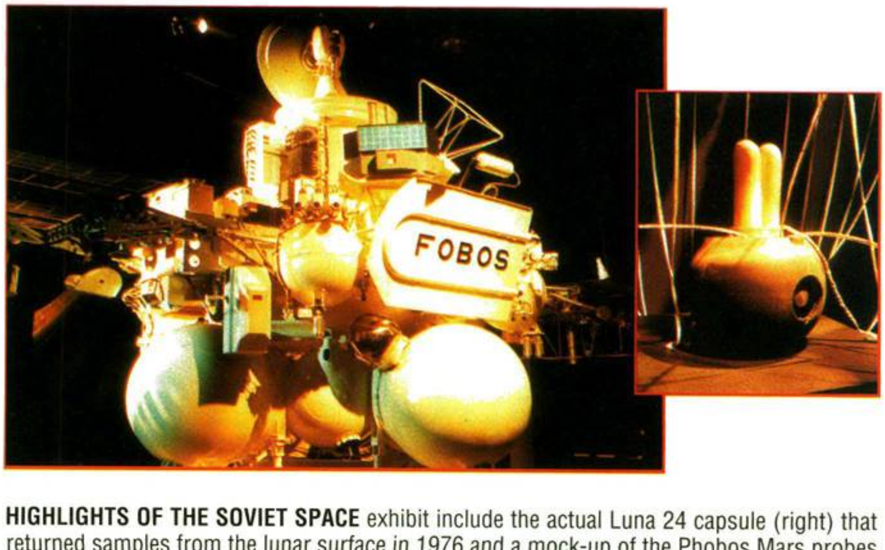
Soviet Space fills a huge exhibit hall with spaceships and satellites that few people outside the now-defunct Iron Curtain have seen before. One of the most notable is a replica of the satellite that shook the world in 1957, Sputnik 1. Just beyond it is an actual crew cabin from a Vostok spacecraft like the one that carried Yuri Gagarin, the first man in space. Farther on, visitors find a silver and white wheeled vehicle gleaming in the spotlights. This is a functional Lunokhod moon rover like the ones that remotely explored the Moon in the early 1970s. The Moon machine peers at passersby with its television eyes and sends its electronic vision to an overhead television screen.

Visitors also encounter the giant VEGA spacecraft. In 1986, two of these unmanned probes explored both Venus and Comet Halley. The five-ton planetary probe looms over the exhibit floor with its solar panels spread like giant wings. Nearby, visitors find the engineering models of the Venera 7 landing capsule, the first craft to land on the surface of Venus, and the VEGA lander, the last probe to reach that tortured place.

A unique highlight of the exhibit is a craft that was once on the surface of another world. In August 1976, Luna 24 landed on the Moon and then returned to Earth with surface samples. The actual beachball-sized Luna 24 capsule, one of three Soviet craft to go to the Moon and return, is there for visitors to touch.

The Soviet Space exhibit also includes the giant ten-meter-tall Granat X-ray telescope assembly, a Soyuz manned spacecraft crew cabin, a Mir space station module, a giant Phobos Mars exploration craft, and dozens more historical artifacts from the previously restricted Soviet space program.

If Soviet Space comes to a city near you, it is well worth seeing. The exhibit was in Ft. Worth, Texas, until January 1, 1992. It then moved on to St. Louis, Missouri, for the next leg of its multi-year stay in the United States. — *Robert Reeves*



HIGHLIGHTS OF THE SOVIET SPACE exhibit include the actual Luna 24 capsule (right) that returned samples from the lunar surface in 1976 and a mock-up of the Phobos Mars probes that reached the Red Planet in 1989. Photos by Robert Reeves.

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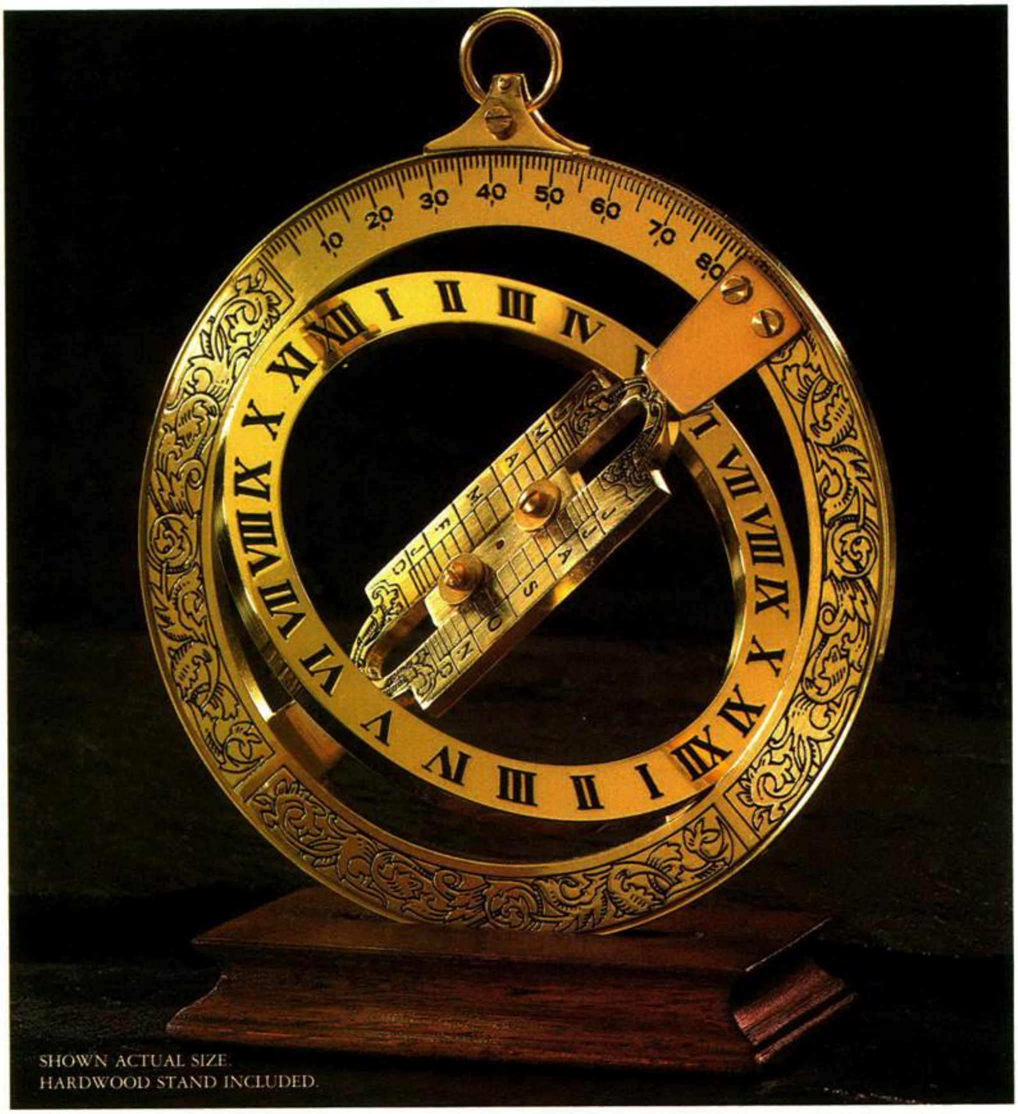

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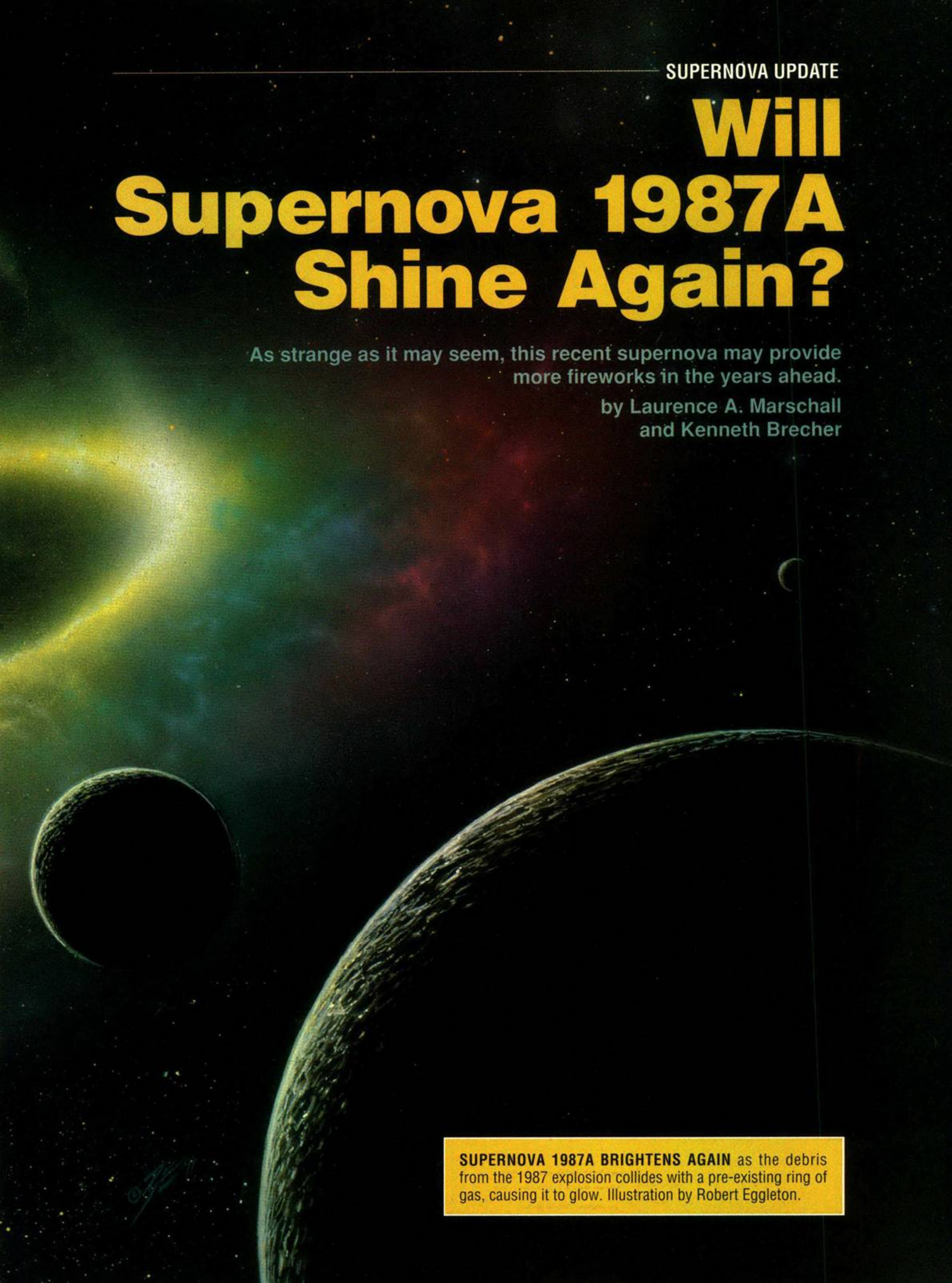
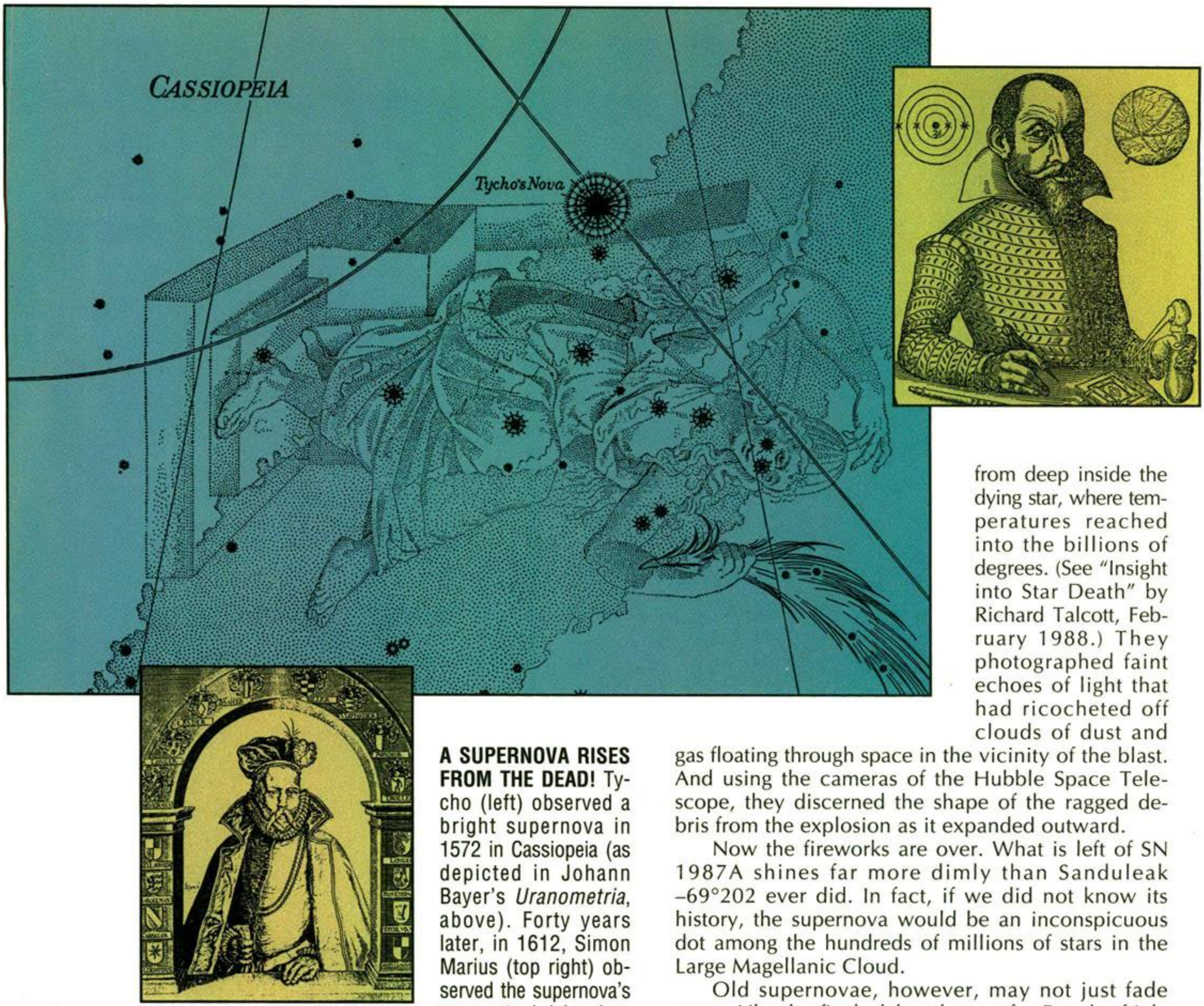
Will Supernova 1987A Shine Again?

As strange as it may seem, this recent supernova may provide more fireworks in the years ahead.

by Laurence A. Marschall
and Kenneth Brecher



SUPERNOVA 1987A BRIGHTENS AGAIN as the debris from the 1987 explosion collides with a pre-existing ring of gas, causing it to glow. Illustration by Robert Eggleton.



A SUPERNOVA RISES FROM THE DEAD! Tycho (left) observed a bright supernova in 1572 in Cassiopeia (as depicted in Johann Bayer's *Uranometria*, above). Forty years later, in 1612, Simon Marius (top right) observed the supernova's apparent rebrightening.

The reports of my death have been greatly exaggerated. — Mark Twain, in a cable to the Associated Press, 1897.

Have reports of the death of Sanduleak –69°202 been exaggerated? This blue supergiant star burst onto the astronomical scene five years ago, on February 24, 1987, as a brilliant point of light visible in the southern sky. Sanduleak –69°202, until then an obscure member of our neighboring galaxy, the Large Magellanic Cloud, had come to a sudden and violent end. The resulting explosion, called Supernova 1987A, has kept astronomers jumping ever since. Because it was the brightest supernova in almost four centuries, SN 1987A provided an unprecedented view of the last days of a massive star, from the exhaustion of its supply of nuclear fuel, through the catastrophic collapse of its innermost core, to the ultimate shedding of its outer layers in a cloud of outrushing debris.

In the months and years following Supernova 1987A, astronomers have been treated to a host of remarkable events. They detected neutrinos emitted from deep inside the dying star, where temperatures reached into the billions of degrees. (See "Insight into Star Death" by Richard Talcott, February 1988.) They photographed faint echoes of light that had ricocheted off clouds of dust and gas floating through space in the vicinity of the blast. And using the cameras of the Hubble Space Telescope, they discerned the shape of the ragged debris from the explosion as it expanded outward.

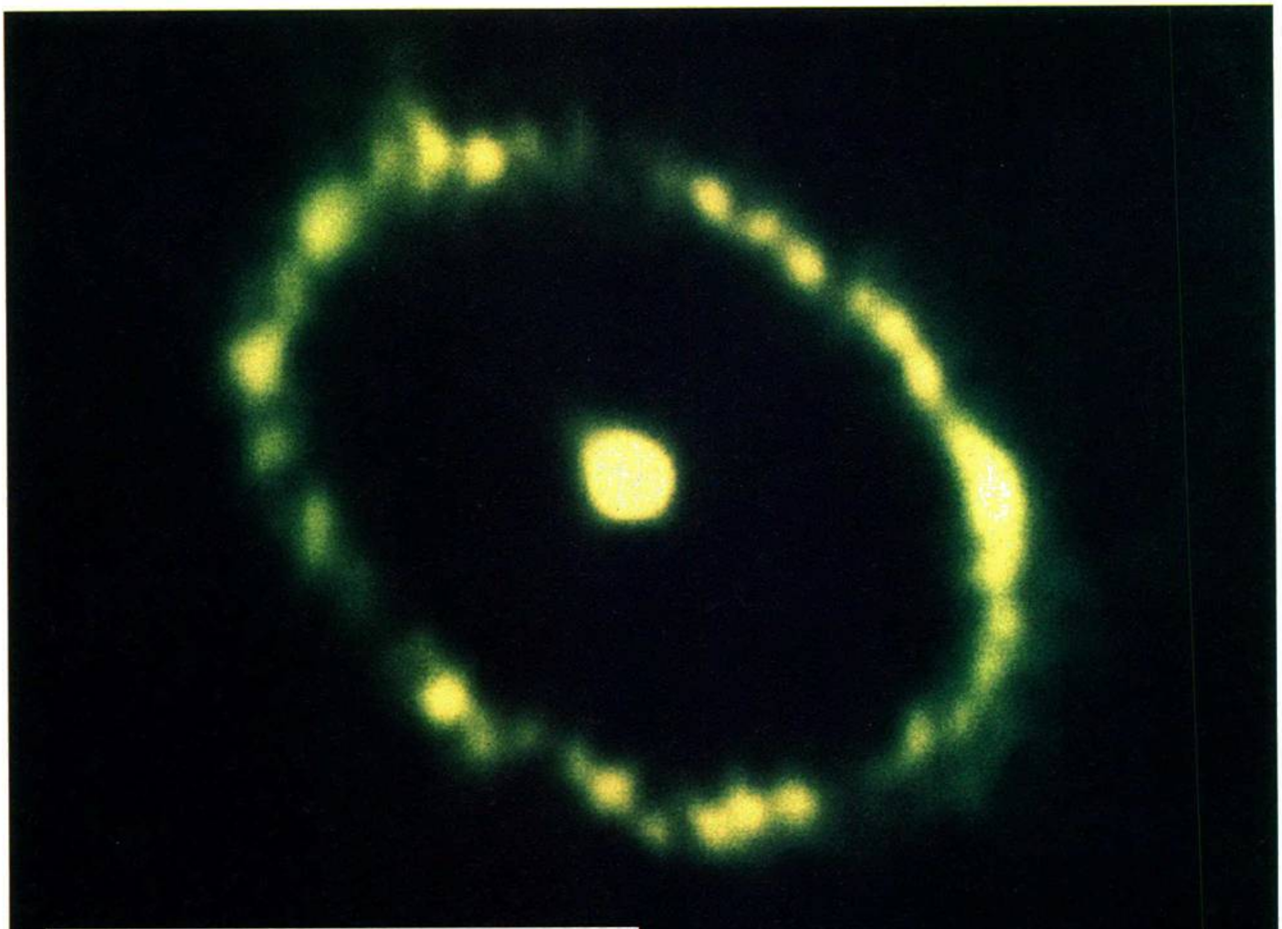
Now the fireworks are over. What is left of SN 1987A shines far more dimly than Sanduleak –69°202 ever did. In fact, if we did not know its history, the supernova would be an inconspicuous dot among the hundreds of millions of stars in the Large Magellanic Cloud.

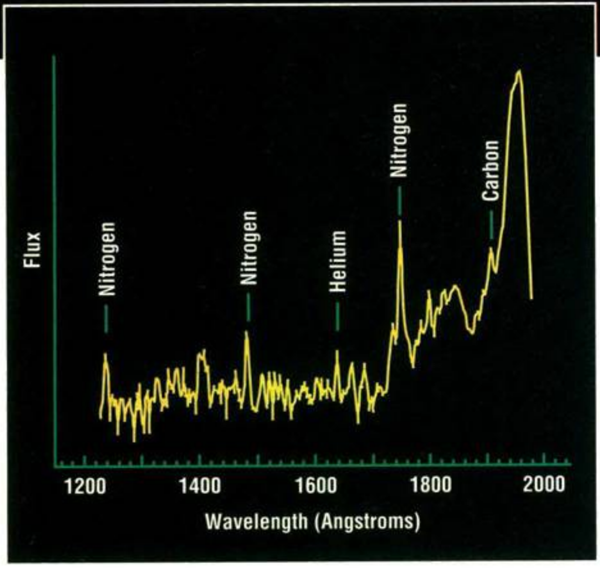
Old supernovae, however, may not just fade away. Like the final, delayed pop of a Fourth-of-July rocket, the final fireworks from a supernova may come years after the initial explosion. Given what we've learned from the behavior of supernovae in the past, it's quite possible that SN 1987A will be rejuvenated, shining again for a brief period at roughly 9th magnitude sometime within the next decade.

Shine again? The very thought seems strange. In the act of becoming a supernova a star is torn to shreds, leaving behind only a small, dense core of neutrons (and often, not even that). Because the body has been cremated and the ashes scattered, nothing remains to rise from the dead. Though variable stars of other sorts may brighten and dim more than once, supernovae, one would think, should have but one brief moment of glory before disappearing forever.

Clues from the Past

That's why it is surprising to discover reports of supernovae coming back to life long after they had faded from view. A remarkable account uncovered by one of us (KB) appears in the writings of Simon Marius, astronomer to the court of Brandenberg at the beginning of the 17th century. Marius was a model Renaissance scientist — colorful, clever, and





THE FIRST INKLING that a ring surrounded Supernova 1987A came from an IUE spectrum (left) that showed strong lines arising from nitrogen in the ring. The ring appeared in all its glory to the Space Telescope's Faint Object Camera (above). Spectrum courtesy Robert Kirshner; photo courtesy NASA/ESA.

quick to adopt new tools of the trade. Using the newly invented telescope (which Marius immodestly claimed to have invented himself) he observed Jupiter's four bright moons and published the first sightings of the Great Nebula in Andromeda.

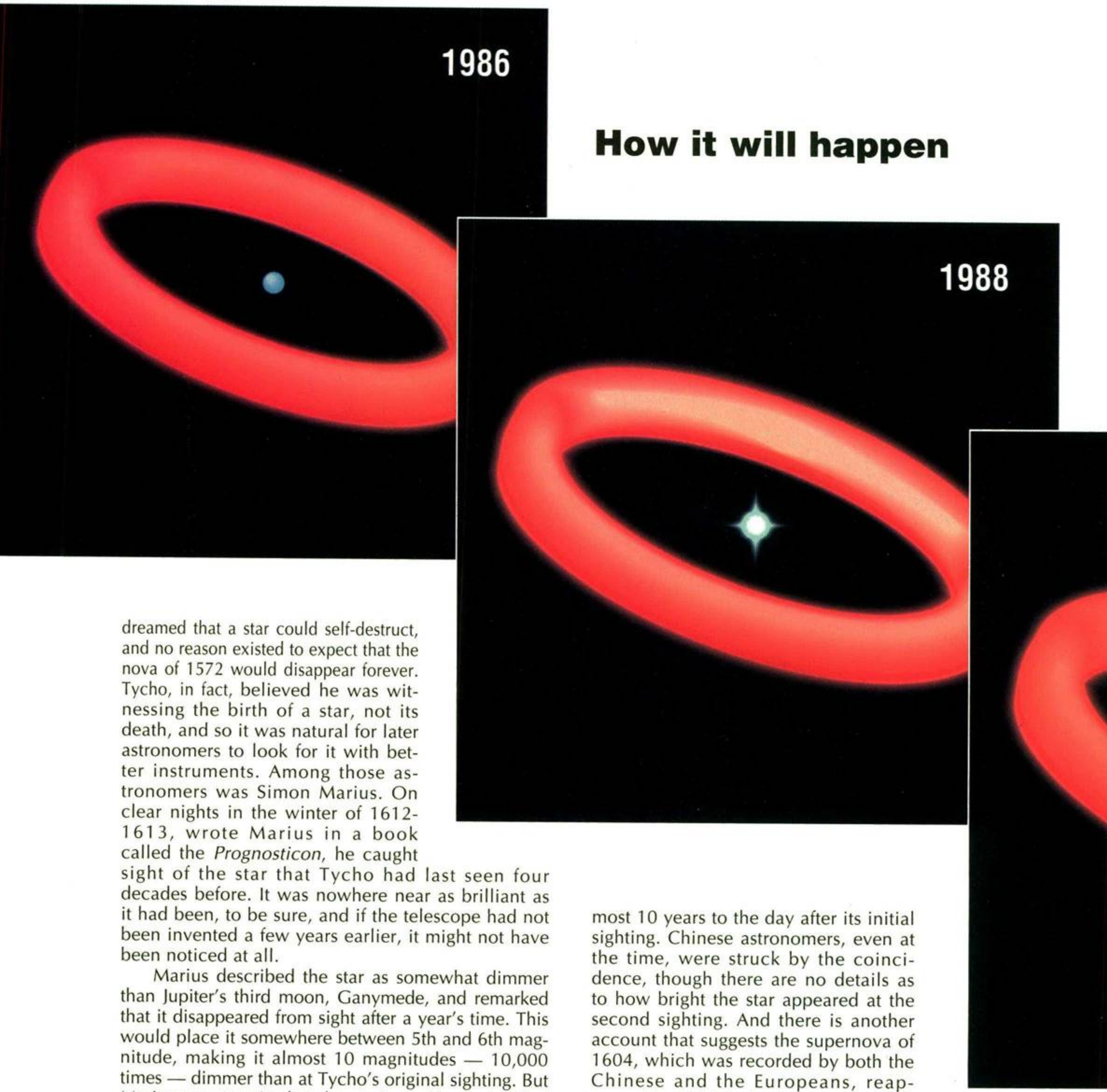
Some of Marius' more extravagant claims angered his more famous contemporary, Galileo Galilei. Incensed by what he considered an encroachment on his territory (he had published the first observations of Jupiter's moons), Galileo called Marius a "poisonous reptile" and an "enemy . . . of all mankind." But modern scholars have praised Marius' meticulous recordkeeping, and his names for the moons of Jupiter — Io, Europa, Ganymede, and Callisto, which were taken from Greek mythology — have long outlasted Galileo's proposal that the moons be named "The Medician Planets" after his patron, Cosimo de Medici.

Marius had worked briefly with Tycho Brahe, the great Danish astronomer. He knew that in the year 1572 Tycho had discovered a bright new star, a "Nova Stella" in Tycho's writings, in the constellation Cassiopeia. In a short book he wrote about the new star, Tycho included a map showing the star's position near the "W" of Cassiopeia, along with a detailed account of the star's behavior. When it first appeared, Tycho noted, the star outshone the planet Venus, and it remained visible to the naked eye for a full two years.

From Tycho's detailed description, modern-day astronomers recognize that the "star" of 1572 was actually an exceptionally bright supernova. Using X-ray and radio telescopes, astronomers can detect a faint remnant ring of gas lingering around the site of the explosion. However, there is no trace of a star at its center.

During Tycho's era, of course, no one even

How it will happen



dreamed that a star could self-destruct, and no reason existed to expect that the nova of 1572 would disappear forever. Tycho, in fact, believed he was witnessing the birth of a star, not its death, and so it was natural for later astronomers to look for it with better instruments. Among those astronomers was Simon Marius. On clear nights in the winter of 1612-1613, wrote Marius in a book called the *Prognosticon*, he caught sight of the star that Tycho had last seen four decades before. It was nowhere near as brilliant as it had been, to be sure, and if the telescope had not been invented a few years earlier, it might not have been noticed at all.

Marius described the star as somewhat dimmer than Jupiter's third moon, Ganymede, and remarked that it disappeared from sight after a year's time. This would place it somewhere between 5th and 6th magnitude, making it almost 10 magnitudes — 10,000 times — dimmer than at Tycho's original sighting. But Marius was certain that the star's position coincided exactly with the mark on Tycho's map of 1572. Modern star maps show no star of comparable brightness within a degree of the 1572 supernova, so it seems unlikely that an observer of Marius' caliber would have mistaken a nearby star for Tycho's.

Evidence of other supernova reappearances can be found in the meticulous astronomical records kept for the emperors of China. According to scholar Wan Jian-Ming, the ancient chronicles tell of more than one such reappearance. The supernova of 1006, the most brilliant supernova ever recorded, shone forth again in the year 1016, almost 10 years to the day after its initial sighting. Chinese astronomers, even at the time, were struck by the coincidence, though there are no details as to how bright the star appeared at the second sighting. And there is another account that suggests the supernova of 1604, which was recorded by both the Chinese and the Europeans, reappeared in 1664. In both years, the Chinese records report a "guest star," or supernova, near the edge of the constellation they called Wei-Suei. (Today we know this region as Ophiuchus.)

Is There Life after Death?

What are we to make of these reports? Observers can be mistaken, of course. Even careful observers like Marius could have been influenced by the desire to see what they expected to see — in his case a new star just beginning to shine. And Chinese astronomers sometimes embellished eyewitness accounts with fanciful stories of sightings that provided astrological support for the adventures of their royal patrons. Thus the reappearances of supernovae in historical times might be no more substantial than sightings of Elvis reported in supermarket tabloids.

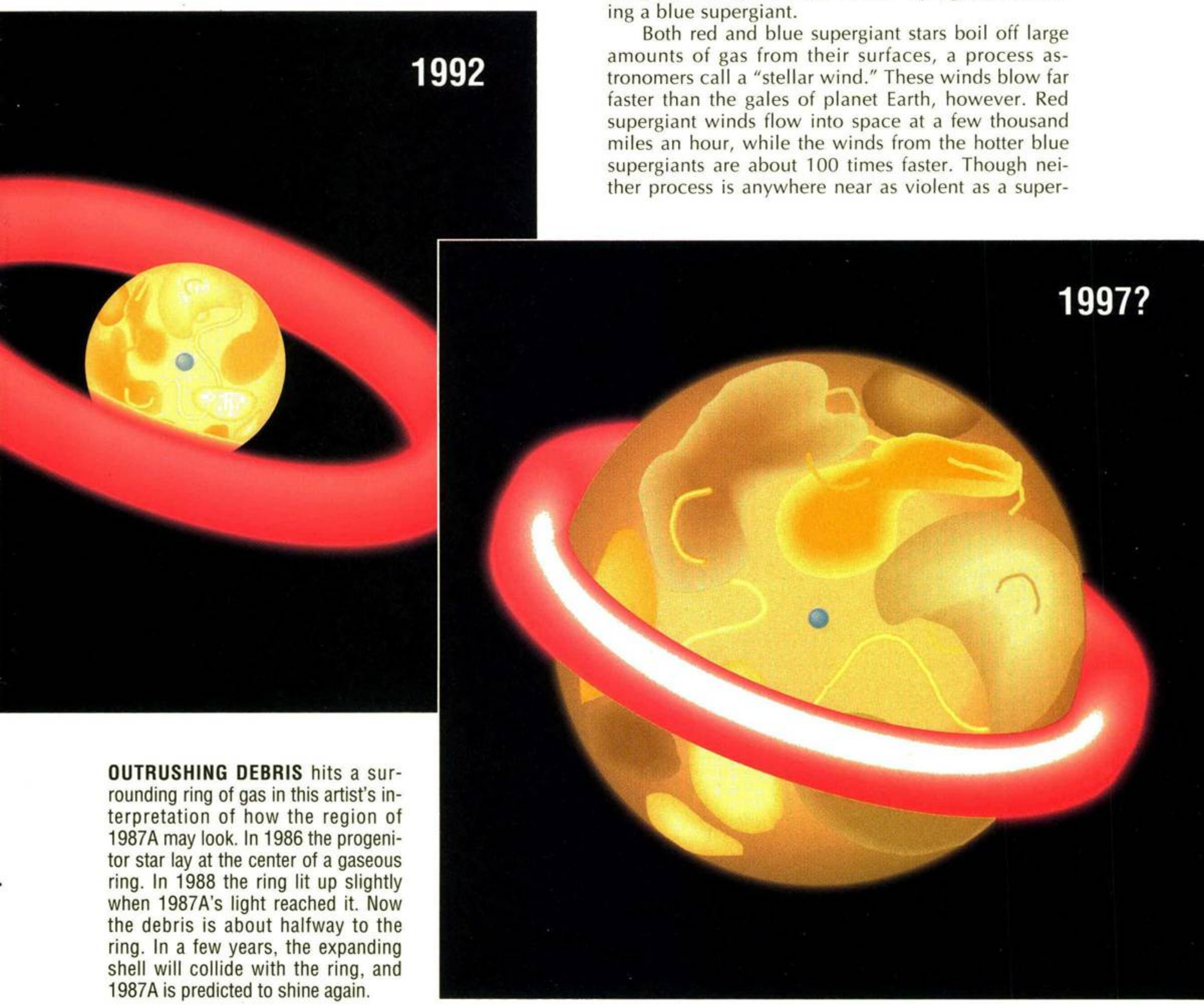
But current astrophysics suggests that supernovae have more of a chance of coming to life again than Elvis does. Shortly after the explosion of Supernova 1987A, these historical reports led one of us (KB) to predict a temporary revival of SN 1987A's light output sometime within the next decade.

The light will come, we believe, not from the star that exploded, but from the outrushing shell of debris the star ejected into the surrounding space. Immediately after the blast in 1987, most of the original mass of Sanduleak −69°202 was shot into space at speeds as high as one-tenth the speed of light. The material is still coasting outward today, an expanding shell containing about 15 times more mass than that in our own star, the Sun.

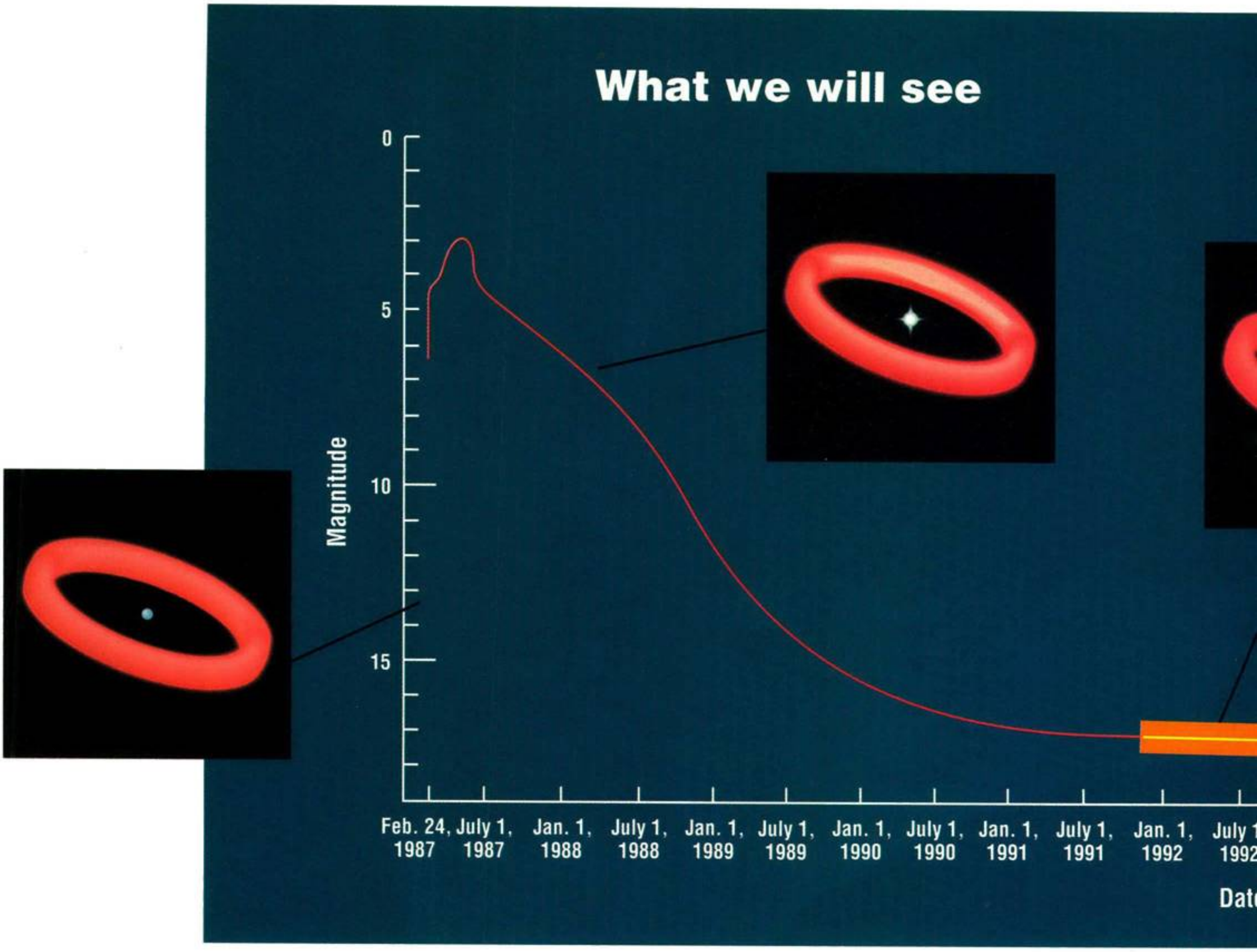
Were there nothing standing in the way, the debris from the supernova would thin out and disappear without a trace. Over 100,000 years or so, it would dissipate into the surrounding interstellar medium, becoming indistinguishable from the thin wisps of matter that drift between the stars. But such is not the case. The expanding shell of debris is on a collision course with another cloud of debris, material shed from Sanduleak −69°202 long before the explosive events of that star's death.

For probably a million years prior to the supernova explosion, Sanduleak −69°202 led the life of an aging star. As it consumed its internal stock of nuclear fuel, its diameter expanded a thousandfold and its surface cooled. It was a red supergiant. Later, in the last hundred thousand years before it died, the star shrank and heated up again, becoming a blue supergiant.

Both red and blue supergiant stars boil off large amounts of gas from their surfaces, a process astronomers call a "stellar wind." These winds blow far faster than the gales of planet Earth, however. Red supergiant winds flow into space at a few thousand miles an hour, while the winds from the hotter blue supergiants are about 100 times faster. Though neither process is anywhere near as violent as a super-



OUTRUSHING DEBRIS hits a surrounding ring of gas in this artist's interpretation of how the region of 1987A may look. In 1986 the progenitor star lay at the center of a gaseous ring. In 1988 the ring lit up slightly when 1987A's light reached it. Now the debris is about halfway to the ring. In a few years, the expanding shell will collide with the ring, and 1987A is predicted to shine again.



What we will see

nova explosion, a substantial cloud of gas can be puffed into space during the lifetime of a supergiant star.

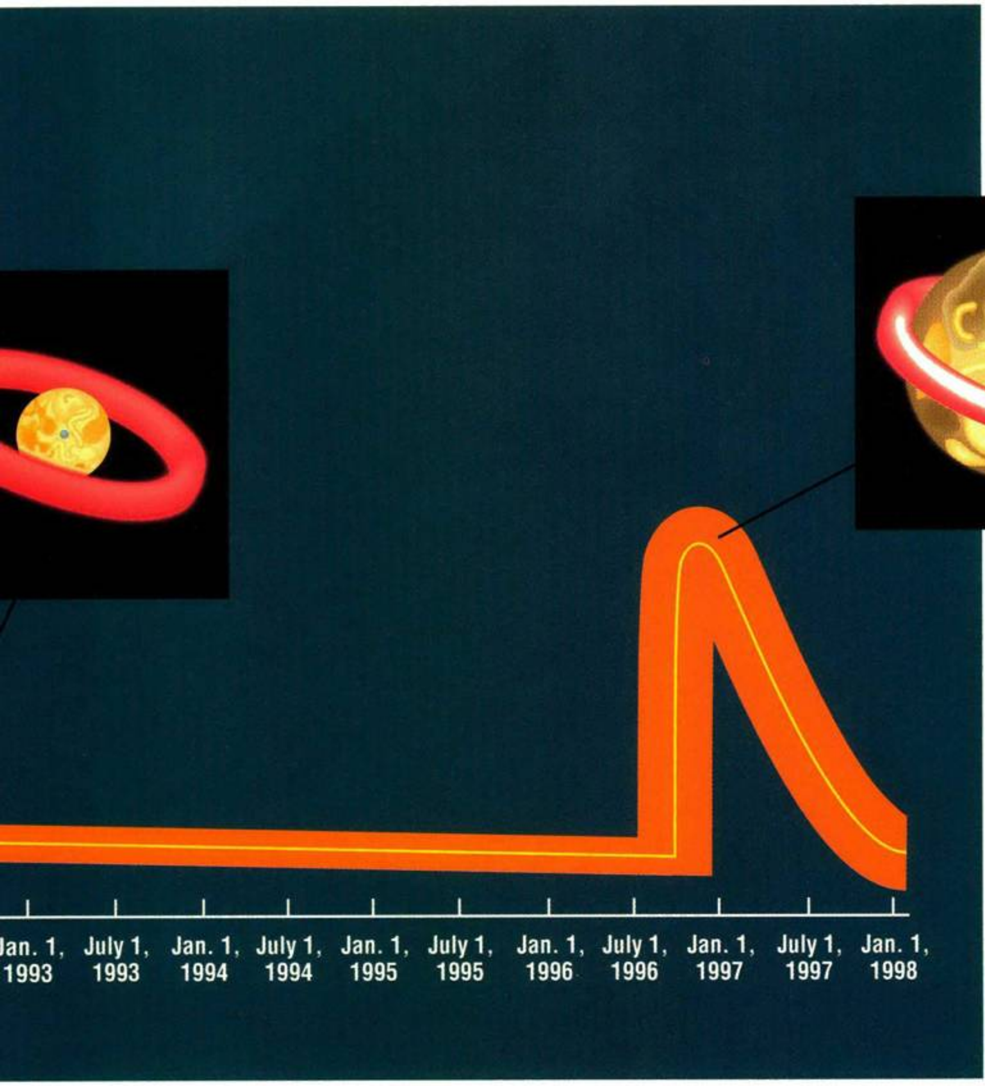
In the case of Sanduleak –69°202, the red supergiant wind carried off several solar masses of material in about a million years. Then in the star's last 100,000 years of life, its blue supergiant wind began blowing, piling up the material from the red supergiant wind that preceded it like a snowplow pushing into a snowdrift. By the time Sanduleak –69°202 was ready to explode, the plowed-up material from the stellar winds formed a ring of gas and dust about a light-year in diameter surrounding the site of the impending supernova.

This circumstellar ring now stands in the way of the expanding debris from SN 1987A. When the cloud of debris hits the ring, sometime within the next decade, the ring will heat up and begin to glow. To observers on Earth the supernova will shine again.

A Shell Game

How do we know that the ring of material is out there? Astronomers have suspected its presence from the first few months after the supernova explosion. The telltale evidence first appeared in spectra taken with the International Ultraviolet Explorer (IUE), a satellite operated jointly by NASA and the European Space Agency. In late May and early June of 1987, these spectra began to show the presence of sharp lines due to the presence of nitrogen, carbon, oxygen, and helium atoms. The spectra also revealed the velocity of this gas, and the motion was far too slow to be coming from material blasted out by the supernova itself. Instead, speculated astronomers, it was gas from a shell surrounding the supernova, lit up briefly by the intense burst of light from the explosion at its center.

The discovery of this circumstellar gas provides a tidy explanation for the mysterious rebrightenings of past supernovae as well as the expectation of more activity from Supernova 1987A. But in 1987 it was impossible to do much more than speculate on what was to come. The circumstellar gas was a phantom presence, otherwise unseen. The glare from the brilliant supernova made it virtually impossible to get pictures of anything in the vicinity for several years. By 1990, however, the supernova faded enough that astronomers finally were able to take high-resolution photographs of the circumstellar gas. A few photos from earthbound telescopes captured light from this gas, but the most striking photo came from the Hubble Space Telescope in late 1990. Taken through a filter that isolates a strong spectral line produced by oxygen gas, the HST photo shows a ring of material about 1.8 arc-



SUPERNOVA 1987A SHOULD BRIGHTEN once more in three to five years. Though the exact time and extent of the brightening are unknown, this light curve shows a plausible scenario. Observed magnitudes to date (in red) courtesy Mark Phillips at Cerro Tololo; future predictions (in gold — the width of the band gives a rough idea of the range of possibility) by Kenneth Brecher.

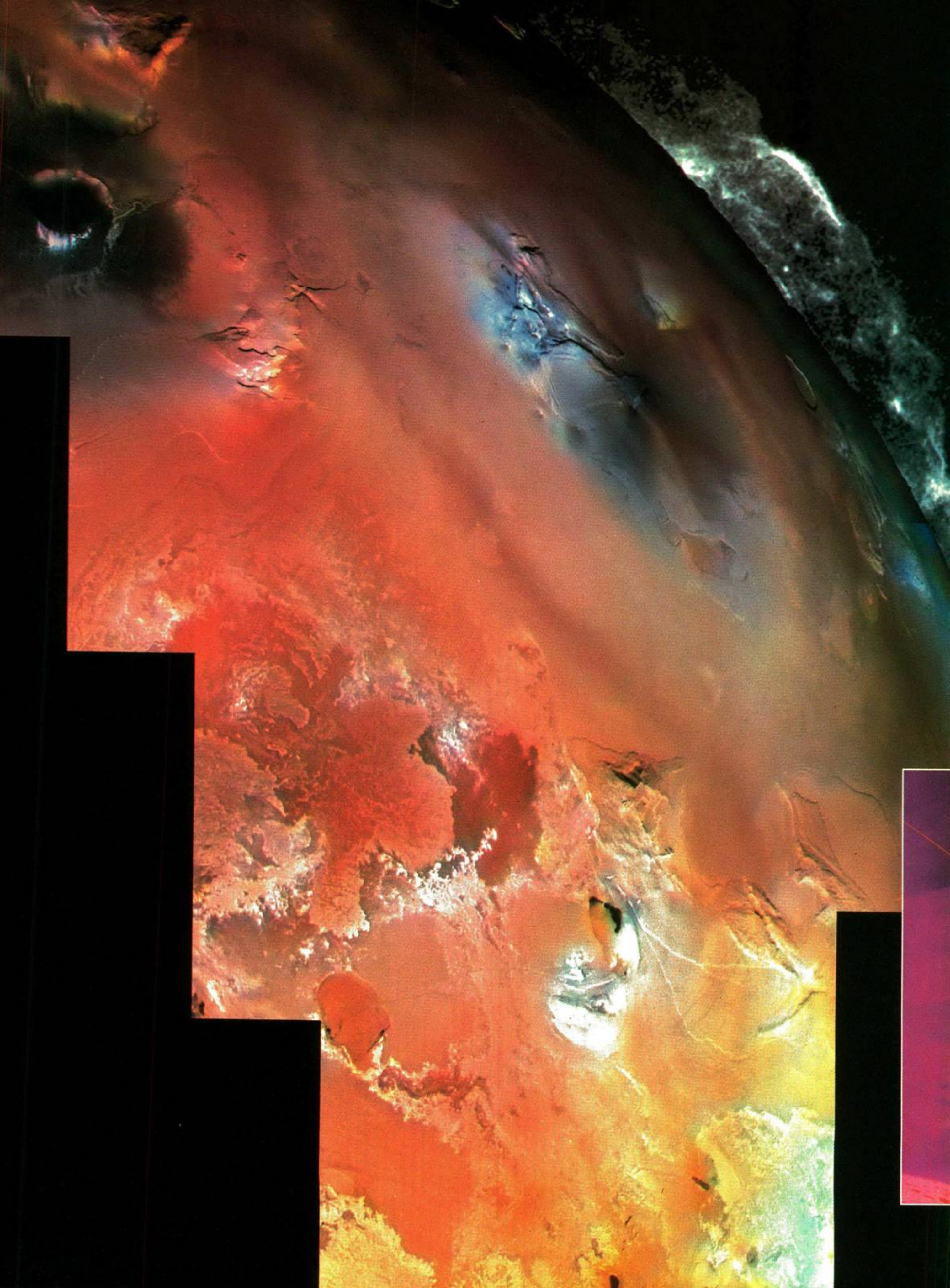
seconds in diameter. Because the supernova lies approximately 170,000 light-years from Earth, that angular diameter places the ring a bit less than 1 light-year from the supernova. With the supernova's debris rushing outward at about one-tenth the speed of light, the first shreds of debris should hit the ring a bit less than ten years after the explosion, or sometime in the mid-1990s.

The collision could come somewhat earlier or later than that because the Hubble image shows only the brightest part of the ring. Astronomers don't know for certain how thick the ring really is, or how far in or out it extends. The fastest-moving shreds of debris from the supernova may reach the innermost gas in the ring several years before they get to the ring's densest parts. As a result, the collision may take place over a long period of time, more like the slow-motion crumpling of two colliding trains than a sudden explosive impact. The first signs of brightening could begin as early as 1995 and extend for a year or more.

We don't know for sure how the collision will appear from Earth, but it clearly will not be as spectacular as the original blast. As the outrushing debris plows into the surrounding ring, the gas will heat up, and the more abrupt the collision, the hotter it will get. The collision will generate radio waves and X rays, which will rise in intensity for a while and then gradually decrease as the clouds slow down and cool off. Dust grains in the debris will heat up and glow, releasing infrared radiation. And hydrogen atoms will be shocked into luminescence, causing the region to brighten visibly with hydrogen's characteristic red glow.

To observers, then, the reborn supernova will appear as a tiny dot of light, as bright as 9th magnitude if the collision is particularly abrupt and intense. Though the entire ring of circumstellar gas may be glowing, it will appear about an arc-second in diameter, and only telescopes like the Hubble will be able to discern any detail. Though not as bright as it was during its brief glory days, it will once more stand out from its neighbors. It will be a fitting last hurrah for a supernova that has given us so much to observe already. ☐

Laurence A. Marschall is a professor of physics at Gettysburg College in Gettysburg, Pennsylvania. His last article for ASTRONOMY was "Supernova Aftermath" — about the Cassiopeia A supernova remnant — which appeared in the February 1989 issue. Kenneth Brecher is a professor of astronomy and physics at Boston University in Boston, Massachusetts and director of the Boston University Science and Mathematics Education Center.



NASA's Never-Ending Mission

Discoveries in the solar system often result from a second or third look at old spacecraft data and sometimes provide startling insight into the character of moons and planets.

By John Williams

If only the walls at NASA could speak. Within the archives of the institution a small mountain of information sits largely unexamined, waiting to share its secrets. The NASA archives hold warehouses full of magnetic tapes and rooms full of CD-ROM disks containing billions of bytes of data from planetary science missions, much of which has never been thoroughly explored. The problem is time and money: scientists receive only so much funding and have only so much time. It is an enviable situation — possessing too much data to handle.

This condition points up a curious aspect of science. Discoveries sometimes wait until second or third or fourth looks at the data, and they often involve more than a little human intuition, ingenuity and, yes, luck. Let's ride along on four spacecraft missions to Venus, Jupiter, Neptune, and Saturn, and look at the nature of the discoveries scientists made both during and after the fact.

PLUMES OF VOLCANIC ASH lie silhouetted against black space along the limb of Jupiter's moon Io. Volcanic activity was recorded in data from Voyager (below), but noticed long after the spacecraft encounter. NASA photos.

Spark of Controversy

All space missions produce a mountain of data. Much of this data fits neatly into existing theories. However, some new ideas spark controversies requiring the defenders to go back and re-examine their data to prove their points. That's how science works. Chris Russell of UCLA, Joe Grebowsky of the Goddard Space Flight Center, Bob Strangeway of NASA, and D.A. Gurnett of the University of Iowa think science is working well at Venus.

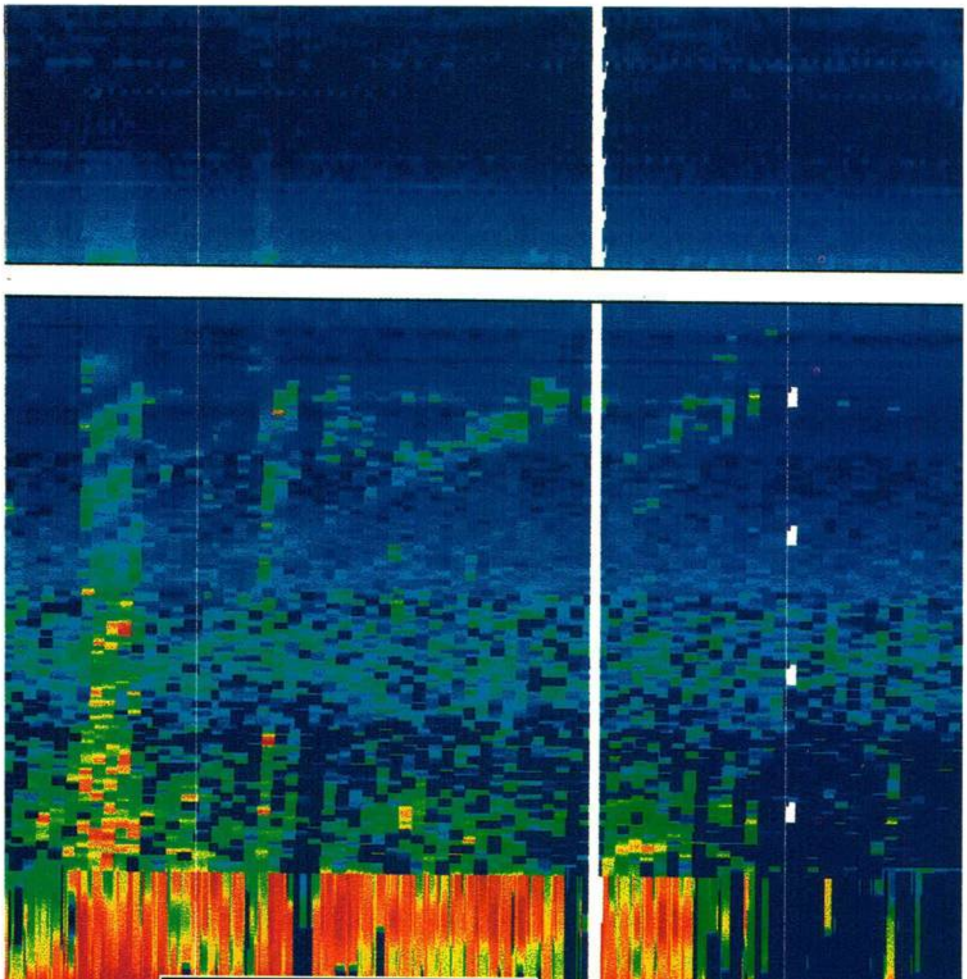
The history of spacecraft exploration of Venus is full of exciting, immediate discoveries. Little was known about this cloud-cloaked sister world until spacecraft first visited it in the 1960s. The Mariner 5 spacecraft discovered in 1967 that the Venusian atmosphere was an incredibly high-pressure environment dominated by carbon dioxide. Soviet spacecraft measured temperatures hot enough to melt lead and zinc. In 1975 two Soviet Venera craft sent back the first pictures of the surface of Venus, revealing a rocky desertlike world with boulders up to 33 feet across.

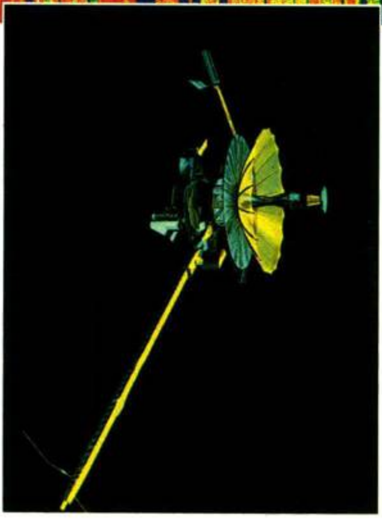
Three years later, Soviet Venera 11 and 12 spacecraft and probes detected electromagnetic waves and flashes that appeared similar to lightning on Earth. In the same year, Pioneer Venus detected similar signals when it started its mapping and observing mission.

Lightning on Earth occurs when air particles ionize due to the presence of strong electric fields. The ionization creates a channel from an area of high charge to low charge, and — Flash! BOOM! — electricity zaps between the two points, usually the sky and the ground but sometimes from cloud to cloud. Lightning has been discovered on Jupiter, Saturn, Uranus, and recently Neptune. But does lightning exist on Venus? The answer lies in the mass of data returned by the Pioneer Venus spacecraft.

Today Russell and the other scientists are busy working with the data collected by the Pioneer Venus Orbiter, one of the four craft launched in 1978. Echoes of the mission continue to spark controversy. From the moment the probe touched down, Russell was certain that the magnetometer on board had detected lightning on Venus. Not everyone was convinced. Grebowsky is searching through the Pioneer Venus data hoping to show that something near the spacecraft produced the curious Pioneer Venus data. Grebowsky does not dispute the existence of lightning on Venus, but he doesn't believe it is the cause of all the electrical discharges that show up in the Pioneer Venus data.

Grebowsky's local events resemble aurorae on Earth. The effects take place in the plasma of Venus' ionosphere instead of the atmosphere. Something is moving





LIGHTNING ON VENUS, visible as ripples in this magnetogram, seems to have been recorded in the data collected by Galileo (left). Magnetogram courtesy D.A. Gurnett.

the plasma, Grebowsky explains, and the electromagnetic waves launched from lightning bolts lack the energy to produce what the astronomers see in the data. He speculates the plasma's movement is caused by cross currents along the planet's magnetic field lines. A charge builds up and launches the 100-hertz bursts observed by the spacecraft.

Strangeway, principal investigator of Pioneer Venus' plasma wave experiment, agrees with Russell and maintains that the evidence supports lightning. "We know what lightning sounds like on Earth. On Venus we're trying to deduce whether or not this is lightning seen from a distance."

Meanwhile, the Galileo spacecraft, en route to Jupiter, is adding fuel to the fire. During its encounter with Venus in February 1990, the spacecraft recorded the whine, pop, and hiss of something that sounds like lightning, according to Gurnett, principal investigator of the craft's plasma wave package.

Galileo zipped by the planet at a distance of 19,000 kilometers (11,900 miles), and its sensitive antenna detected several bursts. The signals it picked up punched right through Venus' ionosphere and resembled static on a car radio during a terrestrial lightning storm. In contrast, Pioneer Venus' Very Low Frequency (VLF) antenna — a product of earlier technology — picked up only whistlers. Whistlers are very-low-frequency radio waves that propagate along magnetic field lines. They are probably not caused by lightning.

With his long history of work on the teams that detected lightning at Jupiter, Saturn, Uranus, and Neptune, Gurnett doubts Galileo's data will settle the 13-year-old debate. He says the craft was just too far away to gather completely believable data about lightning on Venus.

Therefore, scientists will be combing the much greater volume of the 13-year-old data. "Because data is old does not lessen its value," says Strangeway. "Lots of knowledge emerges well after the data has been acquired. Pioneer Venus represents an extremely valuable database that will remain useful for years to come."

A Hot Slice of Pizza

It looks just like a pepperoni pizza! That was the initial thought of scientists after their first close look at Io, one of the four Galilean moons of Jupiter. As Voyager 1 flew past Io, some scientists went out on a limb by proclaiming the surface features appeared to be much younger than the four billion years previously believed. These scientists believed features on the landscape of Io could be as young as one million years.

The immediate science at Io was startling enough. Io was known to be the strangely different Jovian moon: unlike the others, it orbits within an ionized plasma torus and receives a continuous bombardment of charged particles from Jupiter. Voyager revealed Io's landscape as a young world devoid of water but covered with yellow and orange blotches and pockmarked with black. Its surface resembled a crispy pepperoni pizza. "The initial discoveries at Jupiter shook entire points of view," says Candy Hansen, a member of Voyager's imaging team. "Io's surface was so dramatic, like nothing we planned on seeing."

But a later look at an image showed a faint splotch off Io's limb, barely brighter than the inky black background. The image wasn't a good one, but the grainy frame made history. It showed a plume of material shooting away from a volcano near Io's limb. Io had active volcanos, which explained the young landscape features and splotchy surface.

The second look at Io proved to be the key. "We probably would have found the volcanos eventually," Hansen says, "but in real time the eruptions just blended into the background. It wasn't until we enhanced the image and brought the plume out of the background noise that we got our first good look at a volcano on Io."

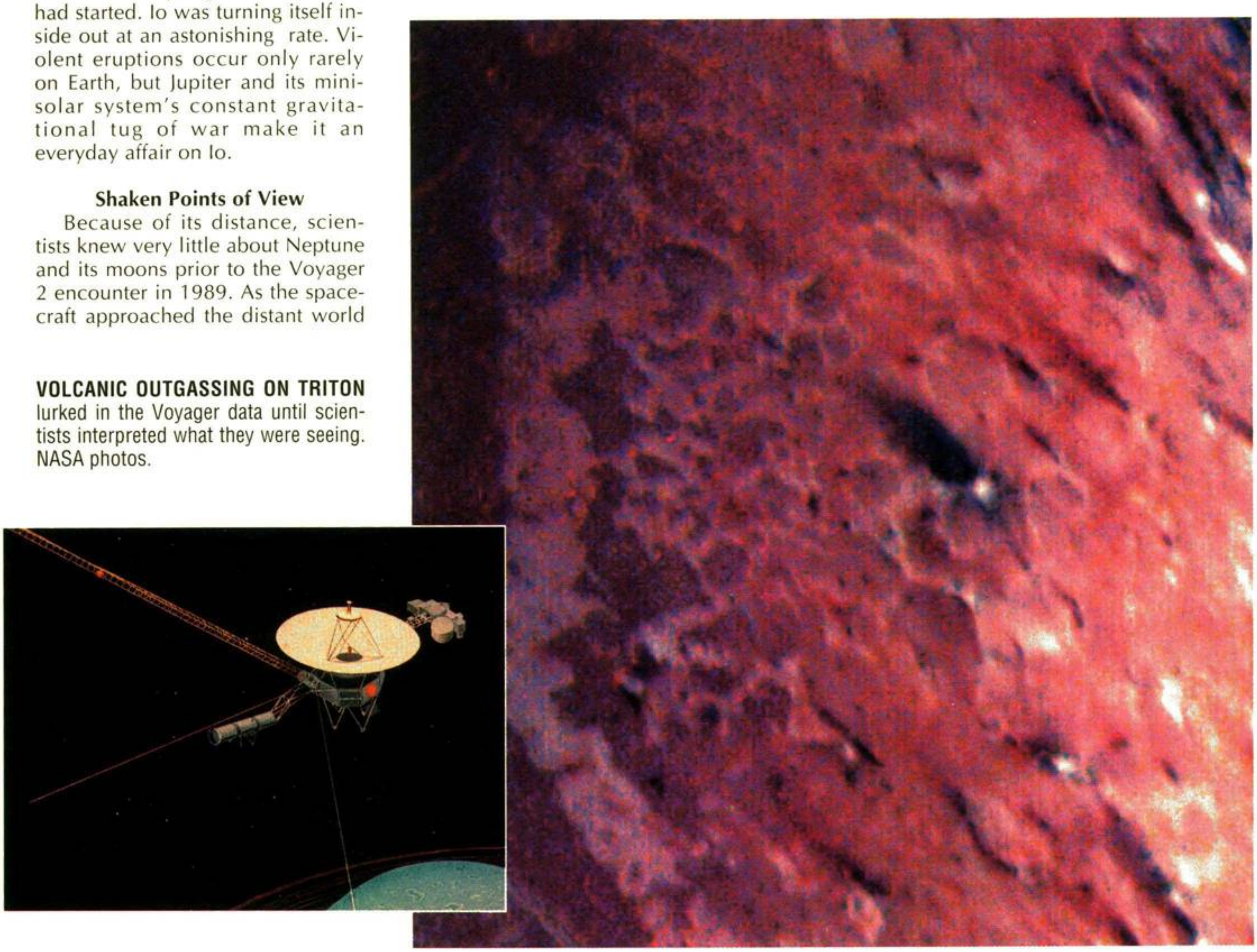
After closely examining the frames, the astronomers found eight plumes spitting material 43 to 175 miles into space. Voyager 1's discovery sent controllers scrambling to change Voyager 2's trajectory to further study the eruptive moon. When Voyager 2 zipped through the Galilean system four months later, six of the volcanos were still erupting and two more had started. Io was turning itself inside out at an astonishing rate. Violent eruptions occur only rarely on Earth, but Jupiter and its mini-solar system's constant gravitational tug of war make it an everyday affair on Io.

Shaken Points of View

Because of its distance, scientists knew very little about Neptune and its moons prior to the Voyager 2 encounter in 1989. As the spacecraft approached the distant world the astronomers saw little in the way of detail: Neptune appeared as a blue disk with its largest moon, Triton, close by. Triton became the focus of interest because it was so large and also because it might, some scientists believed, have unusual or active surface features. Chief among these was the existence of an atmosphere. As the spacecraft drew nearer, however, accurate temperature measurements showed the moon's surface was only 40K above absolute zero. This made it the coldest body in the solar system. Scientists' hopes for surface activity plummeted with the temperature.

Once again, the immediate science at Triton left astronomers breathless. Those working on the Voyager imaging team were taken by surprise with the first closeup images. Cold or not, the moon's highly variegated surface told a tale of geologic activity. Among the features were mysterious streaks indicating that some types of exotic processes had occurred on Triton. What was even more unusual was that the streaks appeared to be in an area that would periodically be resurfaced due to the sublimation of polar ice on Triton. This meant that the streaks must have appeared recently, after the ice sublimated. Much to their surprise, scientists found themselves wondering, could active volcanic processes be occurring on the coldest body in the solar system?

"When we saw the streaks, it was an exciting possibility," says Laurence Soderblom, deputy director of the Voyager imaging team. "I strongly suspected something was going on, but the odds were pretty slim that we'd actually see active geysers." Yet the Voyager imaging team made second, third, and fourth looks through the data and



VOLCANIC OUTGASSING ON TRITON lurked in the Voyager data until scientists interpreted what they were seeing. NASA photos.

carefully analyzed frames, finding evidence of plumes on Triton. "After we saw the plumes were active, we then spent the next week trying to convince ourselves that it wasn't some artifact that could be fooling us," says Soderblom.

Indeed, the search through the data hasn't ended here. Two hypotheses have emerged to explain these phenomena: geysers — like Old Faithful on Earth — or dust devils. The dynamics of the eruption or atmospheric effects must be characterized, plotted, and documented, which might solve the debate. That means a thorough search through the 27,000 images collected at Neptune.

"No one anticipated the types of bizarre phenomena that we see occurring," Soderblom confesses. "Most scientific thinking was that the farther out you got, the greater the liklihood energy sources would go down. Eventually you would get into very lifeless, quiescent environments where nothing would happen for billions of years. But instead we found that the coldest object in the solar system is incredibly active."

Hide and Seek in the Rings

Perhaps the most ambitious use of data resulted from the work of two scientists searching through the mass of material returned by the Voyager spacecraft from Saturn. Due to the gravitational behavior of Saturn's moons and rings, Mark Showalter and Jeff Cuzzi of NASA's Ames Research Center believed that the planet had an undiscovered 18th moon. The two believed such a moon might be hiding in Encke's gap. Determined to find the moon, Showalter wrote a computer program to sift through the nearly 30,000 Voyager images of Saturn for the frames that might reveal the moon.

The immediate science at Saturn had been no less than spectacular. The Voyager spacecraft imaged six previously unknown moons and discovered that Saturn's rings were composed of innumerable ringlets locked in orbit, that there are dark, spokelike features in the B Ring, and that the moon Titan's atmosphere was predominantly nitrogen. Yet the question of another unknown moon nagged at Showalter and Cuzzi.

But not for long. Their computer search paid off handsomely. "Moon number 18 was in the first image I looked at, exactly where

SAVING A NATIONAL TREASURE

During its 33-year history, NASA has launched over 260 successful scientific missions. From the early days of Mariner 2 in 1962, scientists have understood the importance of documenting travels into space. Currently, over one million data tapes containing the wealth of exploration are stored at dozens of sites across the country. It is an ever-growing collection of knowledge about the solar system we live in.

One Voyager image, made up of 5.12 million bits, is jammed with more information than all 21 pictures sent back from Mars by Mariner 4 in 1964. And both the Earth Observing Satellite (EOS) and the Hubble Space Telescope are designed to send back more data and images than all previous missions combined.

The United States has built an impressive planetary database, a national treasure. Some of it, however, is in danger because the storage technology that contains it is becoming obsolete. This matter came under fire from the General Accounting Office in 1990. Congress' watchdog agency charged that irreplaceable data were in danger of being damaged due to storage in "deplorable conditions." The GAO found some of the data stored in dusty hallways and previously flooded basements and other areas where protection from temperature extremes, humidity, fire, and water was lacking.

But even if the tapes are well cared for, few of them may last forever, according to Mike Martin, a technician with NASA's Planetary Data System (PDS) at the Jet Propulsion Laboratory. "We're still reading some magnetic tapes written in the late 1960s, so 20 years is a reasonable lifetime," Martin says. "On the other hand, we have had trouble reading tapes written during the 1989 Neptune encounter. We haven't lost any data, but tapes are hard to replicate and difficult to protect and store." This statement should make everyone with an interest in the future of astronomy scared to death.

The solution to the problem may be transferring everything to CD-ROM disks. The same technology that makes possible listening to symphonies on your CD player may be the perfect solution for NASA's databank. The PDS found that CD-ROM technology is not only cheap but also reliable for periods of up to 100 years. More importantly, one cheap, easily reproduced disk can store huge amounts of data. And because the disks are read by a laser beam they require minimal maintenance — they don't wear out.

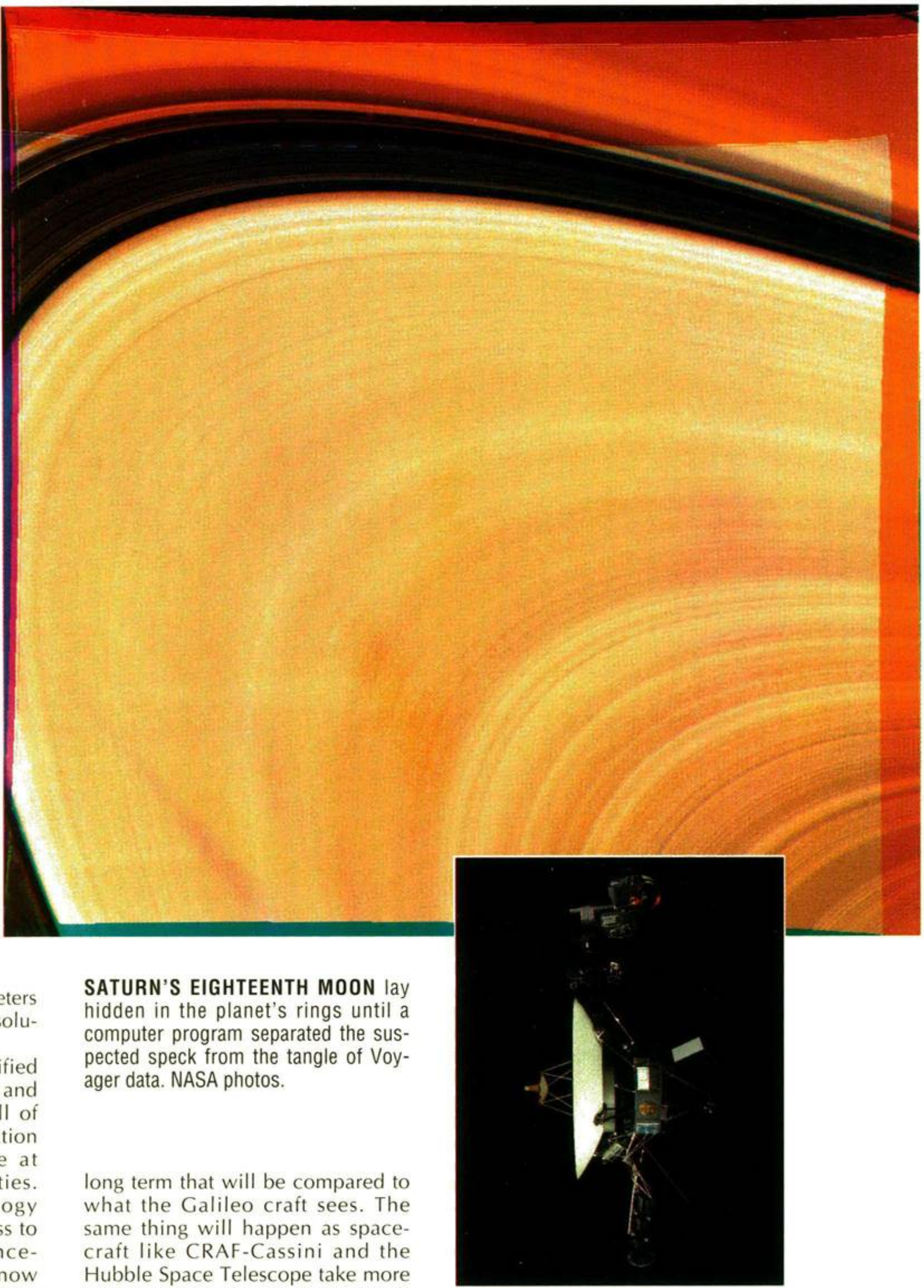
The first major task for the PDS was converting Voyager's Jupiter and Saturn imaging data. Twelve disks represent about 25,000 Voyager images, mostly closeups of the planets and their satellites as well as Neptune and Uranus images. Currently the PDS is working on other projects to convert imaging data from other missions, such as Magellan, to CD-ROM. PDS plans to release 520 disks containing the imaging mosaics from Magellan's radar mapping of Venus. Scientists involved with Galileo and the Mars Observer projects are also considering CD-ROMs for data storage.

"That's what we've always wanted," Martin explains. "Rather than producing magnetic tapes that no one can afford to store, CD-ROMs are cheap, easy, and effective. They're the way of the future." Moreover, CD-ROM represents a shift toward directly distributed data, rather than data kept available on-line from a central clearinghouse. It's a powerful way to get the data into the hands of the astronomers, where it belongs.

we expected it," Showalter says. "I remember being so excited I worked through the Fourth of July." Provisionally designated 1981S13 and later named Pan, the 18th moon was discovered on July 2, 1990. Pan is the smallest moon yet discovered around the giant ringed planet.

For Cuzzi, the Ames scientist who predicted the moon's location, the rings are *terra incognita*. "The data on the rings represent an unexplored wilderness that we're just now starting to poke our way through," he says. "Unquestionably many of the big discoveries at Saturn came right away, but we can't forget that storehouses of information subtly hide in the data, and it takes great effort to dig it out."

Before computers eased the task, however, searching for moons was time-consuming, miserable work. To get an idea, imagine staring at lots of grainy images with thousands of rings, enhancing one, and staring at it some more in search of a tiny bright spot. The moon Showalter found did not even occupy one complete pixel, one of the 640,000 tiny blocks that make up a single Voyager image. Pan is a mere 20 kilometers across, just under Voyager's resolution of 30 kilometers.



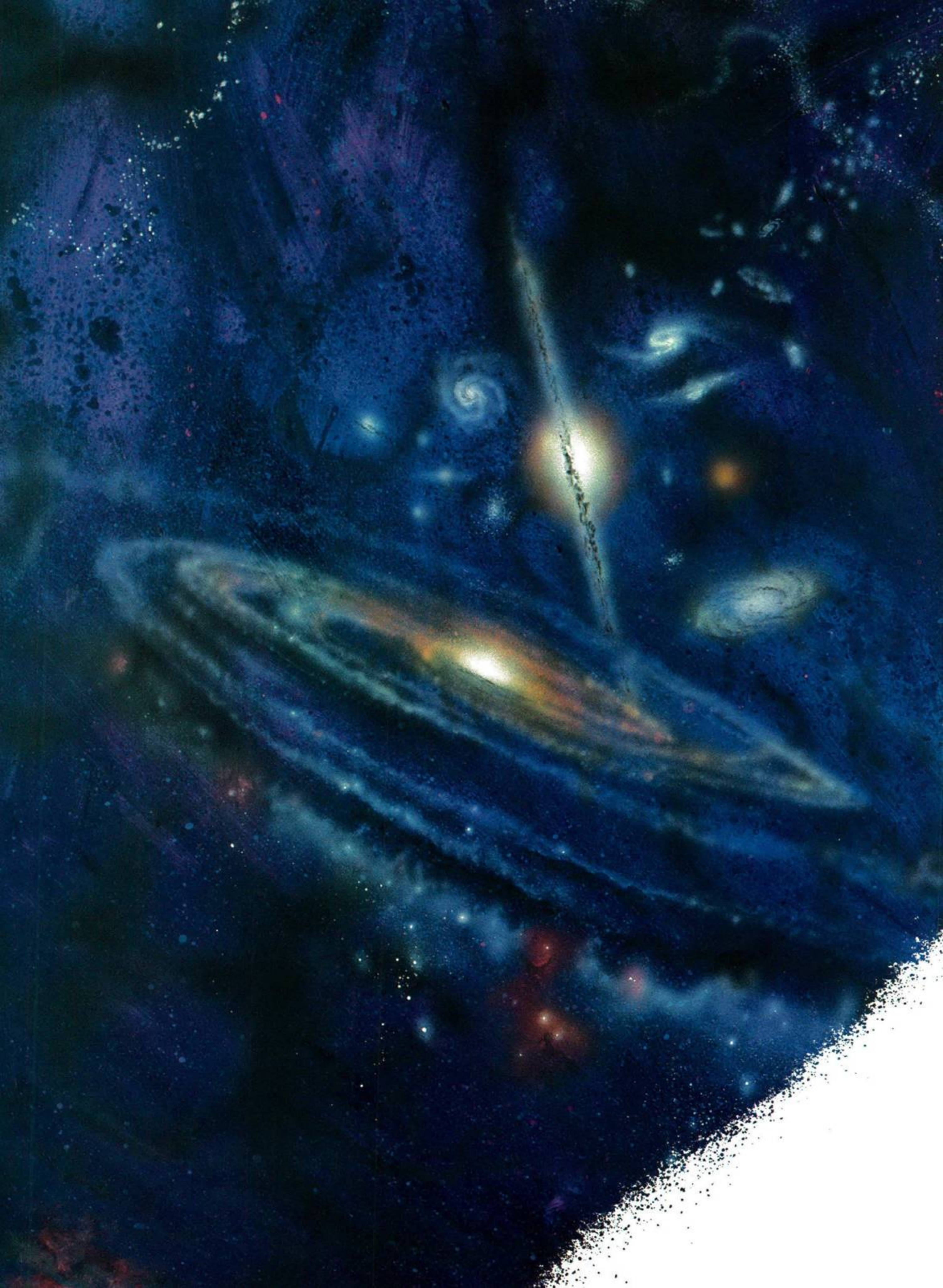
SATURN'S EIGHTEENTH MOON lay hidden in the planet's rings until a computer program separated the suspected speck from the tangle of Voyager data. NASA photos.

Showalter's task was simplified by recent advances in imaging and storage technology. Almost all of the U.S. space science information is stored on magnetic tape at NASA facilities and universities. Recently, CD-ROM technology has allowed easy, instant access to images for study and enhancement. A two-month process now requires a mere 30 minutes. The long and laborious process of getting data on magnetic tapes has been replaced by an instant process thanks to CD-ROM-equipped computers.

Where will this newfound technology lead planetary astronomers? "I'm sure there will be a huge renaissance of looking at Voyager data when Galileo gets to Jupiter," predicts Candy Hansen. "The analysis will go on and on and on. We now have a historical record over the long term that will be compared to what the Galileo craft sees. The same thing will happen as spacecraft like CRAF-Cassini and the Hubble Space Telescope take more and more planetary data. We'll compare the old stuff with the new, and that will lead to more discoveries."

When we return to the planets with a second round of spacecraft, scientists will rush to review the old data — to chart changes in atmos-pheres, magnetic fields and satellite geology. Over time, armed with a growing historical database, scientists will begin to piece together an overall picture of the solar system in its historical, evolutionary context. They will compare changes over time — a necessary step in refining theories about the solar system's origin and the Sun's place in the Galaxy. ☐

John Williams is a freelance writer living in Kansas City, Missouri. His last article was "Built to Last" (December 1990).



DARK MATTER PERMEATES the universe, from clusters of galaxies to the galaxies themselves. Even the destiny of the universe may be controlled by this unseen matter. Painting by Michael Carroll.

COSMOLOGY

Shedding Light on Dark Matter

We can't see it, but we know it's all around us. It's called dark matter.

by Richard Monda

Fritz Zwicky uncovered a mystery in 1933, one astronomers are still trying to solve. Zwicky, a Caltech astronomer, found that the universe contains more matter than we see. This unseen matter deeply interests astronomers because its gravitational influence may control the destiny of the universe.

The first hint that dark matter exists came from observations of galaxy clusters. Zwicky measured the motions of galaxies in the Coma cluster and realized that the individual galaxies were moving too quickly for the cluster to stay together for a long period of time. The motion of each member of the cluster should have caused the cluster to fly apart long ago. Yet even backyard telescopes show that the cluster remains intact.

Zwicky concluded that the cluster must be ten times more massive than it appears in order for the cluster to remain gravitationally bound. This enormous mass discrepancy indicates that ninety percent of a cluster is invisible. Also, because matter in the universe clumps to form galaxies and galaxy clusters, the mass discrepancy implies that 90 percent of the *universe* is invisible.

At first, astronomers called the material "missing mass," but the term is misleading. Zwicky's observations show that the mass is there. "Dark matter" is a better term because it is the light emitted by the material that is missing.

There are cosmological implications to the existence of dark matter. The standard cosmological model predicts that the universe continues to expand and cool after the initial big bang. If, however, there is sufficient mass in the universe, the expansion will be slowed and possibly even reversed. Therefore, the amount of dark matter controls the expansion — and destiny — of the universe.

In spite of the obvious importance of dark matter, astronomers do not know the form of this matter. The list of discarded candidates gets longer each year, yet the form of dark matter remains murky. But we know where it is. It permeates the space between galaxies and the galaxies themselves.

Dark Matter in Galaxies

Just as the motions of galaxies *in* clusters indicate that matter lurks unseen in the cluster, the motions of stars give evidence for dark matter in galaxies. Vera Rubin, an astronomer at the Carnegie Institution of Washington, measures how quickly stars rotate about the center of galaxies. Plotting the stars' rotational speed versus their distance from the galactic center yields a rotation curve. Our Galaxy's rotation curve reveals that most of the galaxy — perhaps out to 300,000 light-years — rotates like a rigid wheel. Rubin's work conducted over the last two decades shows that other galaxies behave the same way.

Her results were surprising because astronomers expected stars to orbit a galaxy in the same way that planets orbit the Sun. Mercury, the innermost planet, speeds along at 30 miles per second, while the outermost planet, Pluto, plods at 3 miles per second. In contrast, stars in the Milky Way Galaxy move at roughly 150 miles per second, regardless of their distance from the center. The only possible explanation is that the visible part of the Galaxy is surrounded by large amounts of unseen matter.

Besides rotation curves, there is other evidence for dark matter. Astronomers find from the orbital motions of globular clusters that the Galaxy's mass is much larger than that of visible matter. The conclusion is inescapable. Ninety percent of the mass of the Galaxy must be in the form of dark matter. The most likely location for this mass is in the halo surrounding the Galaxy.

The ratio of a galaxy's mass to its luminosity, or energy output, also supports the existence of dark matter. For stars like the Sun, the ratio is roughly one (one solar mass divided by one solar luminosity). Hot stars have ratios less than one because they emit lots of energy for their mass. Conversely, the ratio is greater than one for low-mass, faint red dwarf stars.

Visible matter in our Galaxy, which largely contains red dwarfs, has a mass-to-luminosity ratio of 2. But the ratio of total mass to luminosity is five times higher. The high total mass-to-luminosity ratio is found also in other galaxies and ranges from 10 to 30. Binary galaxy systems and clusters of galaxies have ratios as high as 300. Large amounts of dark matter are needed to explain these ratios.

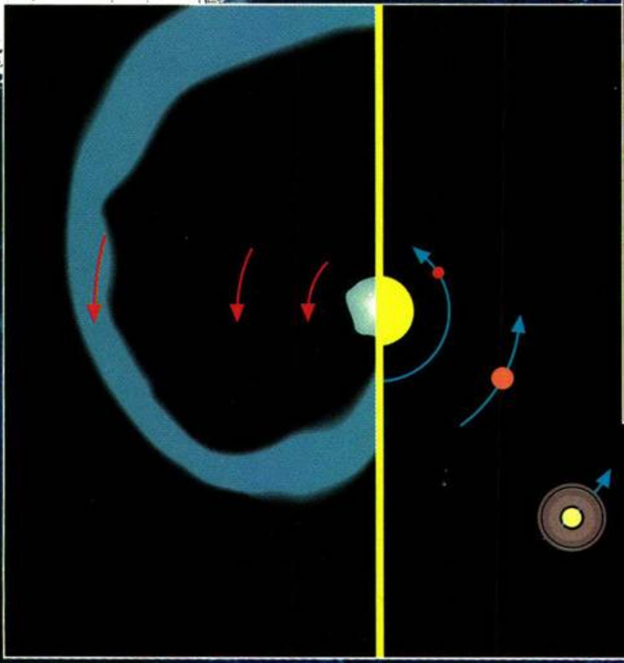
After 60 years of observation, in short, astronomers conclude 1) that galaxies and galaxy clusters must contain 10 times more matter than we can see and 2) that mass is most likely contained in the halo surrounding galaxies and in the spaces between galaxies. What isn't known, though, is the form of this invisible matter.

What Dark Matter Isn't

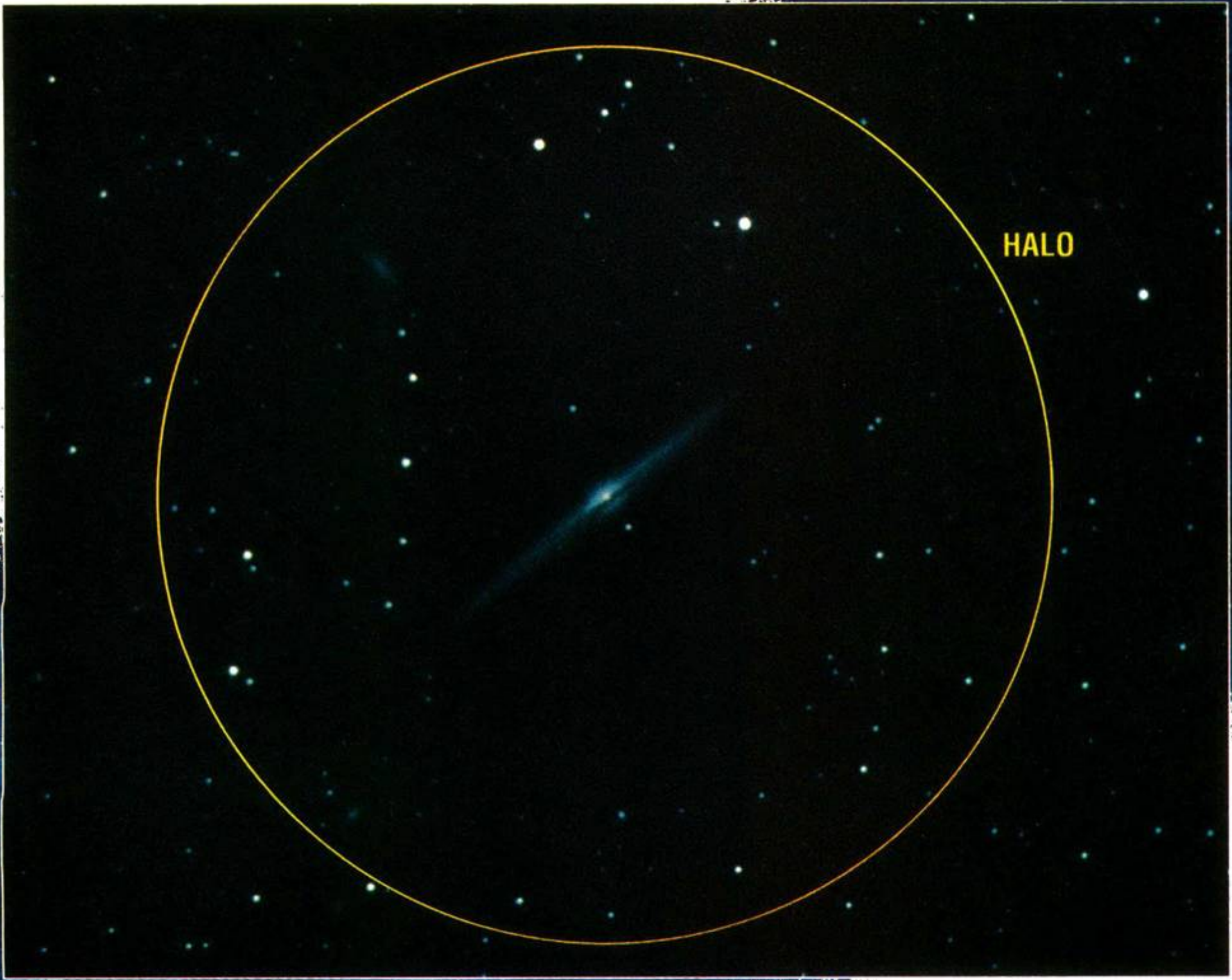
There are so many possible forms for dark matter that it is easier to state what it *isn't*.

We know it isn't atomic hydrogen gas because we would detect

A HIGH MASS-TO-LIGHT RATIO means most of the galaxy's mass is dark matter. M101 photo by Tony Hallas and Daphne Mount.



GALAXIES ROTATE at nearly constant speed rather than like the planets in our solar system.



MASSIVE, FAINT HALOS SURROUND galaxies with dark matter. NGC 4565 photo by Jim Baumgardt.

radio emission from gas clouds. Likewise, optical radiation from ionized hydrogen gas clouds would betray their presence. Even molecular hydrogen would show absorption lines in the spectra of distant objects as light from these objects passes through the gas cloud.

We know it isn't dust, for large amounts of dust would obscure light from distant galaxies more than is observed. Dark matter can't be stellar mass black holes or neutron stars either. Gas falling into these objects would emit more X rays than satellites have observed.

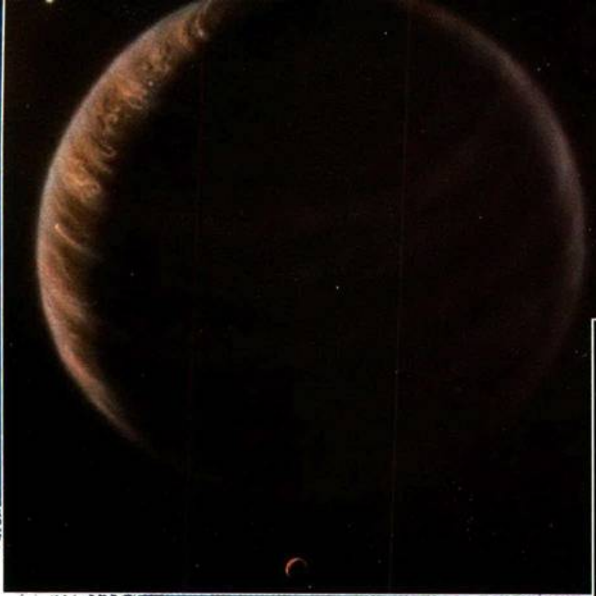
None of these radiation signals are detected by astronomers, so dark matter is not in the form of gas, dust, stars, or black holes. However, there are many other possible candidates such as brown dwarfs, black dwarfs, Jupiter-sized bodies, or exotic particles.

Brown and Black Dwarfs

Most stars visible in the Galaxy are faint, low-mass red dwarfs. But astronomers predict that even smaller objects, brown dwarfs, exist that are fainter and cooler than red dwarf stars. Brown dwarfs are at least 80 times more massive than Jupiter. They are more than just large planets, however. They form as stars do from large gas clouds and produce energy for a short time through nuclear reactions.

To explain dark matter in the Galaxy by brown dwarfs alone, there would have to be at least 200 times the estimated number of red dwarfs. Far fewer probably exist, since the efforts of several groups of astronomers have produced only a handful of brown dwarf candidates (see "Do Brown Dwarfs Really Exist," April 1989). Some astronomers conclude that while brown dwarfs may contribute to dark matter, they do not exist in sufficient quantity to provide the large amount of observed dark matter.

Black dwarfs are another possibility. These objects are not failed stars like the brown dwarfs but stars that have run through their entire life cycle. A black dwarf is the ultimate endpoint for a low-mass star like the Sun. Such a star is black because it no longer emits light and, hence, is impossible to detect directly. But that isn't the biggest problem with black dwarfs: it takes too long to make one.



PLANETS MAY ROAM the galaxy, adding to its mass. Painting by Adolf Schaller.

FAILED STARS CALLED brown dwarfs each contain little mass but may be numerous. Painting by Mark Paternostro.

When massive stars "die," they quickly end up in their ultimate endpoint as a neutron star or black hole. But low-mass stars must first become a white dwarf. The white dwarf slowly cools as it gives off light and eventually becomes a black dwarf. Astronomers estimate it takes at least 10 billion years — the age of the Galaxy — for a white dwarf to become a black dwarf. Therefore, the Galaxy probably doesn't contain any black dwarfs, which turns our search for dark matter to yet another candidate.

"Jupiters" on the Loose

Planets should exist in the Galaxy in large numbers. Although most stars in the Galaxy are part of binary systems, many stars, like the Sun, are single. The formation process of these stars should have left large Jupiter-like planets orbiting them.

Despite attempts to detect these planets indirectly through motions of the star introduced by the planet's gravity, there are presently no confirmed detections of planets. (Direct sightings will be attempted with the Hubble Space Telescope when the telescope optics are corrected.) This suggests that either there are fewer planetary systems than first thought or the planets have low mass. In either case, planets alone are not the solution to the dark matter problem.

Exotic Particles

The absence of brown dwarfs, black dwarfs, and other planetary systems has driven astronomers to look for other dark matter candidates. One promising possibility is the high-energy particle "zoo." There are many contenders, such as photinos, gravitinos, and neutrinos.

The early universe was a sea of energy unlike today's matter-dominated universe. This energy-rich environment acted like an ultra-high-energy accelerator, creating nuclear particles we presently only envision. The high-energy phase of the universe's history ended less than a second after the big bang, but some of these exotic particles may still exist in the universe. Of particular interest is the class of particles called WIMPs. These Weakly Interacting Massive Particles are difficult to detect because they do not easily interact with other forms of matter. This low interaction makes them ideal candidates for dark matter.

Like other candidates for dark matter, most of these predicted particles have not been detected as yet. One exception is the neutrino. The Sun produces countless billions of neutrinos in its core as hydrogen is converted into helium. However, astronomers detect fewer neutrinos than predicted by models of the Sun's interior. One possible explanation is that the neutrino has mass — like protons and electrons but unlike the massless photons — and, therefore, interacts more strongly with other material inside the Sun than theory predicts. Currently, though, researchers believe that even if the neutrino has mass, it is too small to contribute significantly to dark matter.

Astronomers and physicists have joined in the search for other predicted particles. But in contrast to other candidates, such as brown dwarfs, not having detected these particles keeps interest high. Their large mass, potentially high abundance in the universe, and lack of interaction with visible matter (which keeps them in the dark) make these particles prime candidates for dark matter.

Cosmology and Dark Matter

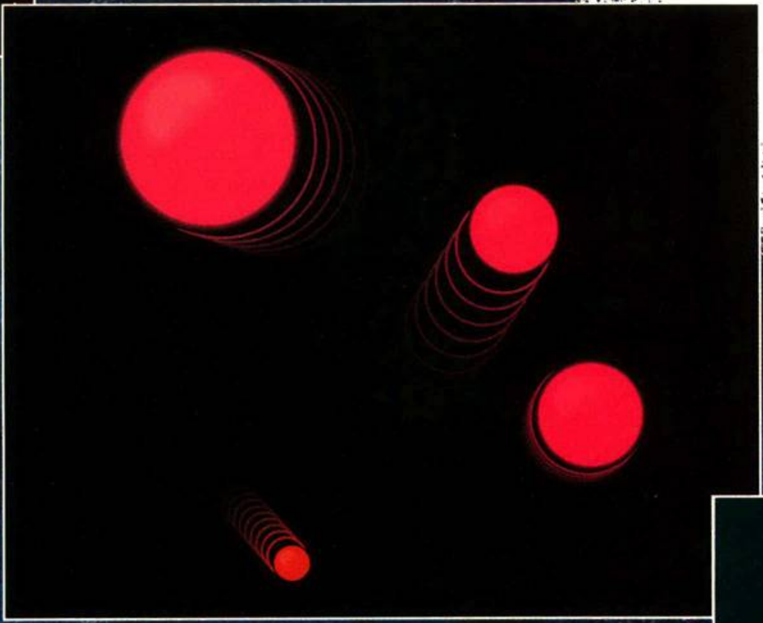
Despite the many possibilities, astronomers still do not know the form of dark matter. But even without knowing its form, the cosmological implication of dark matter is clear. If there is sufficient material, the mutual gravitational attraction of objects in the universe will eventually halt the present expansion and cause the universe to collapse. On the other hand, if there is not enough material, gravity is too weak to slow the present expansion and the universe will expand forever. If the amount of mass is just right, gravity will bring the expansion to a halt but will be too weak to make the universe collapse. The expansion rate in this last case is called the critical speed.

The visible mass contained in the universe is 1,000 times less than needed to halt the expansion and even including present estimates of dark matter, the mass is still 5 to 10 times too small to cause the universe to collapse. To cause the collapse, the mass-to-luminosity ratio of galaxy clusters must be at least seven times greater than the largest ratio presently observed. Yet inflationary models of the universe predict that the expansion rate should be nearly the critical speed. Perhaps there is even more dark matter yet to be found in the universe.

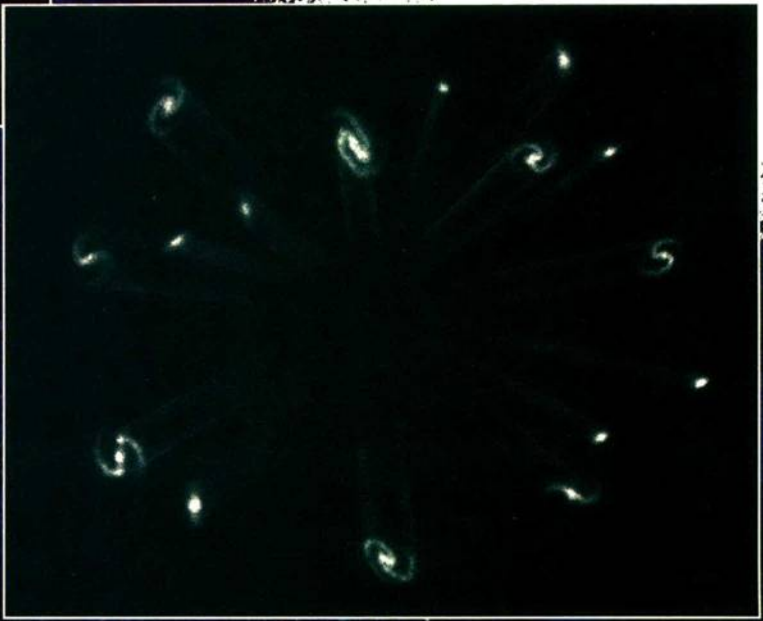
How pervasive is dark matter? It is directly detected in galaxies and galaxy clusters. It might also exist in the space between clusters of galaxies and in the space between clusters of clusters. Astronomers have detected voids in the larger fabric of the universe where galaxies are not found. If dark matter exists in these regions, a major problem in astronomy may shift from how matter clumps in otherwise uniform space to what causes galaxies to form only in some regions of space.

As crucial as unseen matter is to our understanding of the size, shape, and mass of the galaxies and to the structure and destiny of the universe, we know only where it is located. There doesn't seem to be enough of it to stop the expansion of the universe and we know almost nothing about its form. Only one thing is really clear at this time. Astronomers are just beginning to shed light on dark matter. ☐

Richard Monda is the director of the Schenectady Museum Planetarium in New York.



EXOTIC PARTICLES LEFT OVER from the Big Bang may be the source of the dark matter.



ASTRONOMERS PRESENTLY BELIEVE there isn't enough mass in the universe, even with dark matter, to stop its expansion. Painting by Victor Costanzo.

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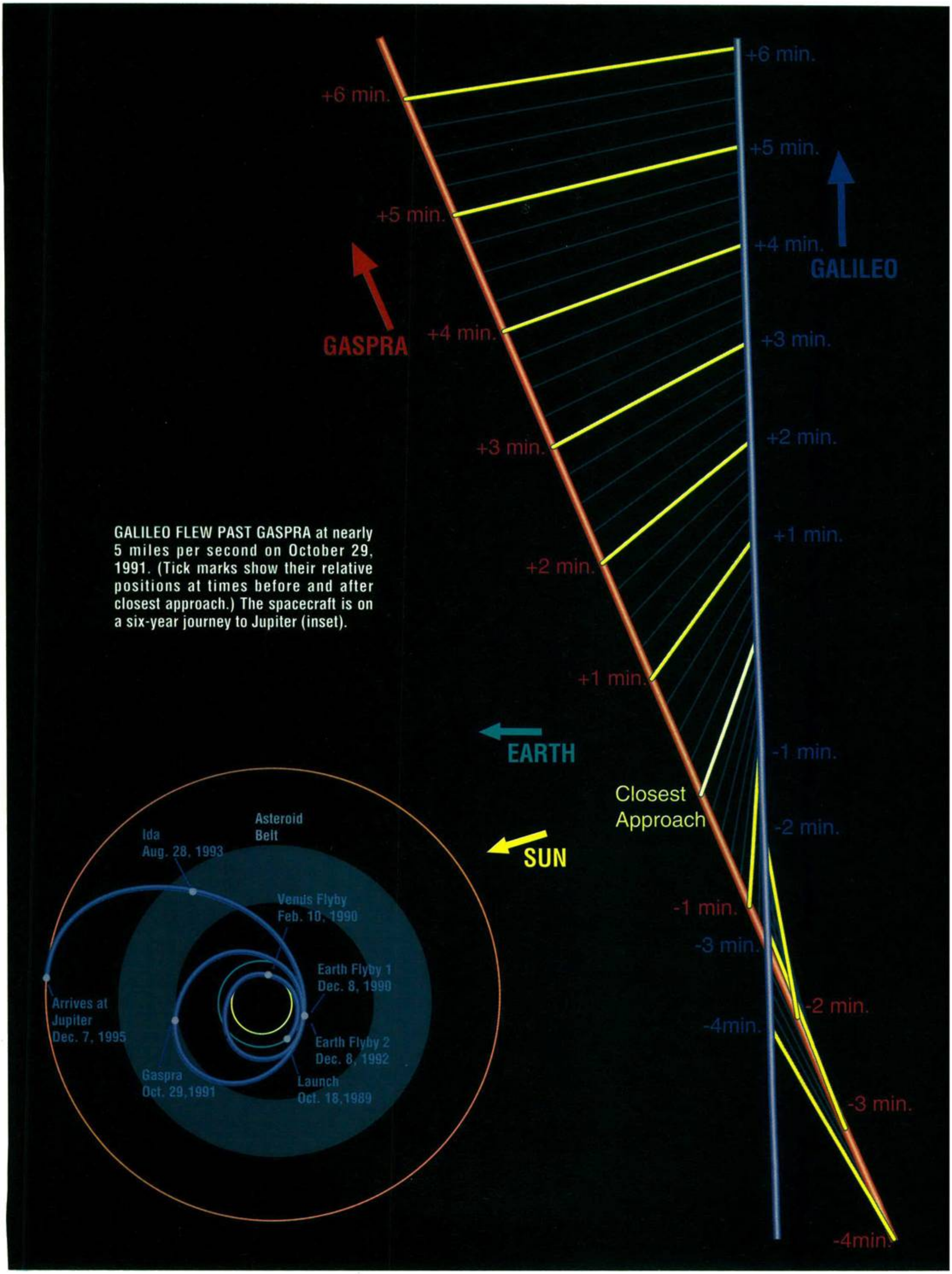
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GALILEO FLEW PAST GASPRA at nearly 5 miles per second on October 29, 1991. (Tick marks show their relative positions at times before and after closest approach.) The spacecraft is on a six-year journey to Jupiter (inset).

THE FIRST ASTEROID FLYBY

Galileo views Gaspra

Galileo's recent encounter with Gaspra tantalizes astronomers with the first closeup look at an asteroid.

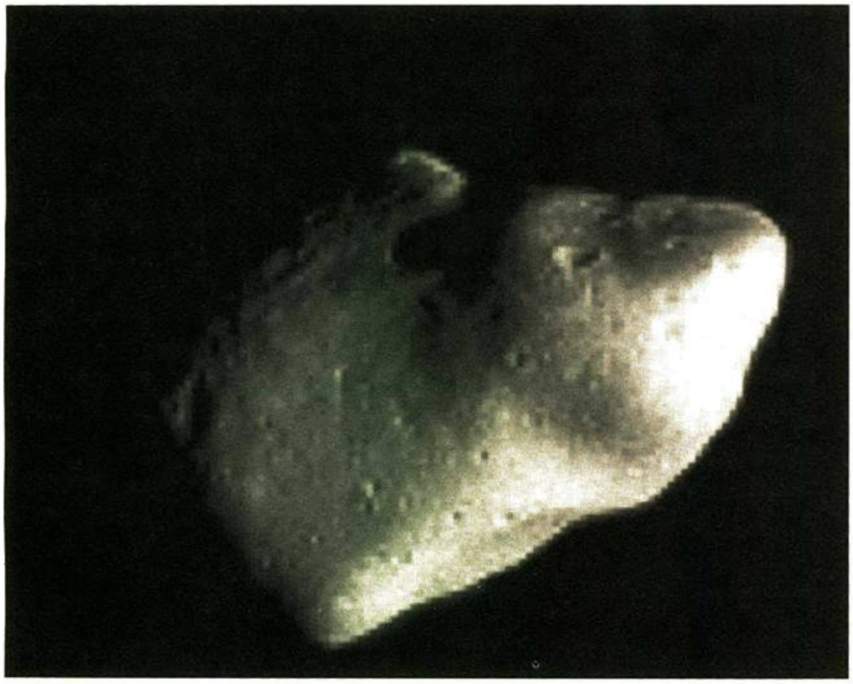
by Richard Talcott

During the last three decades, astronomers have studied at close range nearly every class of object in the solar system. Spacecraft have flown by every planet and major satellite except the most distant — Pluto and its companion, Charon. They have landed on the Moon, Venus, and Mars. And six years ago, a flotilla of spacecraft scrutinized the most famous comet of all, Comet Halley.

Of all the types of objects that orbit within the Sun's sphere of influence, only asteroids remained untouched by human presence. Until now. At the end of October, the Galileo spacecraft flew past tiny Gaspra, snapping the first closeup images and making the first *in situ* measurements of an asteroid's environment. In early November, Galileo transmitted to Earth the first of these images.

Asteroids have long piqued astronomers' interest. Like comets, they are relics from the early solar system — remnants of the material that produced the planets 4.5 billion years ago. And Gaspra, like many asteroids, is probably a fragment of an older and larger asteroid. Thus Galileo's flyby of Gaspra should provide a new perspective on the conditions prevailing in the early solar system. It should tell us about collisions among the planet-forming bodies as well as about the extent of internal heating that took place inside larger asteroids. Unfortunately, because of a balky antenna on Galileo, it may take until late this year before astronomers retrieve all the unique data.

Galileo's high-gain antenna — the main communications antenna designed to return data from Gaspra and later from Jupiter — remains inoperable. The antenna failed to unfurl properly last April and subsequent attempts to open it have not been successful. The spacecraft's tape recorder stores all the science collected at Gaspra. It will be transmitted to Earth either through the high-gain antenna when that is fixed or through the operational low-gain antenna shortly before Galileo makes its second Earth flyby this coming December.

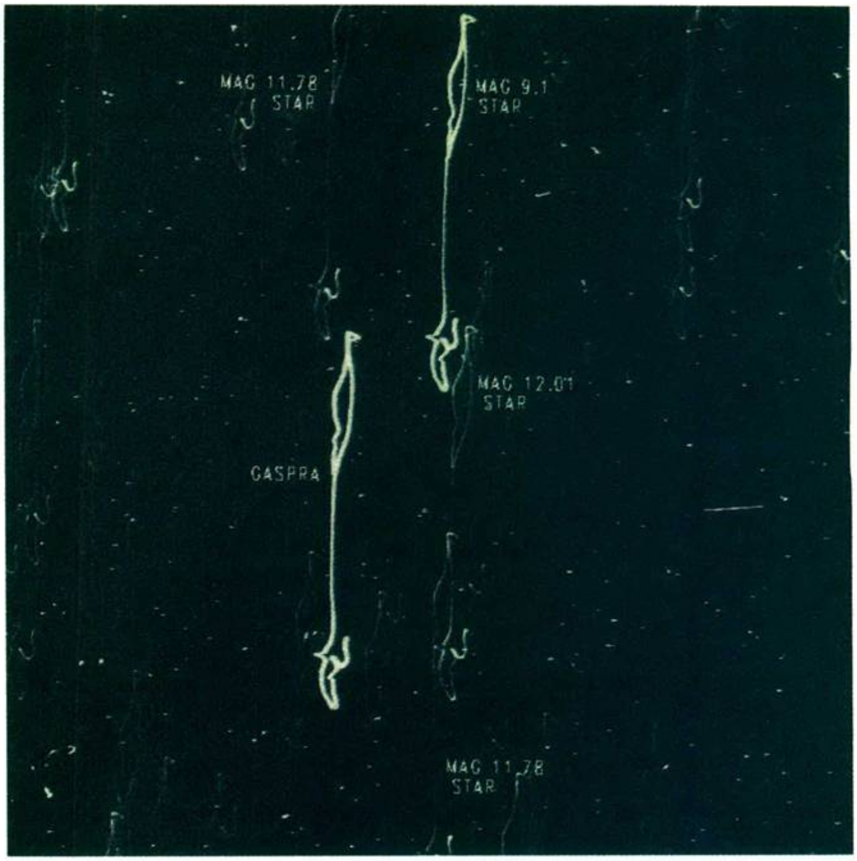


GASPRA'S CRATERS and indentations tell a tale of catastrophic collisions in the asteroid's past. Galileo snapped this image from 10,000 miles away. NASA/JPL photo.

Close Encounter of the First Kind

As Galileo sped by Gaspra on October 29, it turned an array of sophisticated instruments on the asteroid. The first was the imaging camera, which began shooting pictures of the asteroid as early as last September. The photos revealed no details, but then they weren't intended to. They were optical navigation images, taken to pin down Gaspra's position so the spacecraft's instruments could be pointed accurately during the actual encounter.

Although astronomers knew the location of Gaspra well enough to find it easily in Earth-based telescopes, they needed a much better fix to fly a spacecraft within 1,000 miles of the asteroid. That's what the optical navigation effort gave them. The craft scored a near bull's eye, coming within three miles of the targeted spot. The pinpoint accuracy meant that the



GALILEO SCORED A BULL'S EYE thanks to optical navigation photos such as this. Gaspra and the star images appear as streaks in this October 13 exposure because astronomers slewed the camera. NASA/JPL photo.

Galileo flight team did not have to send a series of last-minute commands to the spacecraft's computer to override the preprogrammed encounter sequence.

Galileo began taking scientific images and spectra only a few hours before closest approach. As Galileo bore down on the tiny asteroid, it snapped 150 images, 126 of which came in the final hour. The images returned to Earth in November were taken from a distance of 10,000 miles and resolved details as small as about 500 feet across.

Galileo showed Gaspra to be a dark, irregularly shaped chunk of rock and minerals measuring approximately 12 x 7 x 7 miles. Several large indentations appeared on Gaspra's limb, and ridges crisscrossed the asteroid's surface. In addition, Galileo revealed a multitude of small craters, ranging from over a mile in diameter down to the limit of the camera's resolution.

There is also evidence for a series of grooves, perhaps similar to those on the Martian moon Phobos, at the limit of Galileo's resolution. The nature of these should be apparent when Galileo's best images, which have a resolution three to four times better than those returned in November, are sent to Earth later this year.

Based on the early images, members of the Galileo science team believe Gaspra is almost certainly a fragment of a larger parent body that suffered numerous catastrophic collisions. The number of small craters on the asteroid's surface suggests that the last of these great collisions occurred approximately 300 million to 500 million years ago.

Besides the camera, the spacecraft's spectrometers, magnetometers, and dust and plasma detectors all studied Gaspra. Telemetry sent back as Galileo blazed past the asteroid at 17,600 miles per hour indicated that all the instruments functioned flawlessly. Still, astronomers will have to wait to see the fruits of their labors.

Beyond Gaspra

Gaspra was but a way station on Galileo's six-year journey to Jupiter. Yet if the spacecraft's main antenna isn't fixed within the next four years, the Gaspra flyby may prove to be a bigger highlight of the mission than anyone had planned, or hoped.

NASA engineers have narrowed the problem down to three adjacent ribs that are still bound to the antenna's mast. Unless they can somehow coax the stuck ribs free, the orbital tour at Jupiter is in serious jeopardy. Sophisticated computer models suggest that the trick to releasing the antenna is to perform a number of "cooling turns," in which the spacecraft is turned so the antenna faces away from the Sun and cools down. The chilled antenna then shrinks slightly, and with luck the jammed ribs are freed.

The engineers planned a third cooling turn for December, when Galileo was at its farthest point from the Sun in its current orbit. If the tactic worked, by the time you read this the spacecraft may be in the pink of health and the Gaspra data already in astronomers' eager hands. If the tactic failed, we may have to wait until a month before Galileo's Earth flyby in December to see all of the Gaspra data. That flyby will boost Galileo's velocity enough to send it on to Jupiter, a long journey that will see the spacecraft grow colder and colder. Although the engineers are not overly optimistic that the December cooling turn will work, they are very confident that they are on the right track and repeated cooling turns will eventually free the antenna.

What if the antenna remains stuck when Galileo reaches Jupiter in late 1995? The first part of the mission — the atmospheric probe that will penetrate the Jovian cloud tops — should be unaffected. Much as the Gaspra data was stored in the onboard tape recorder, the probe's data would be relayed to the orbiter and recorded, to be transmitted slowly to Earth through the low-gain antenna.

But the orbiter's 22-month mission to study the Jovian system would essentially be lost. At Jupiter's distance, the high-gain antenna can transmit 134,000 bits of information in one second, enough to return an image to Earth in about one minute. The low-gain antenna could transmit only 40 bits per second, so the same image would take 20 hours to transmit. For all intents and purposes, the orbiter would be mute.

Faced with this worst-case scenario, however unlikely, NASA engineers would resort to even more aggressive tactics. One possibility would be to fire the spacecraft's rocket thrusters repeatedly to jiggle the antenna free. Although this would pose a significant risk to the spacecraft, it might be the only way to salvage Galileo's primary mission. □

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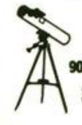

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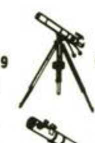

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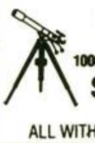

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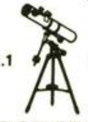

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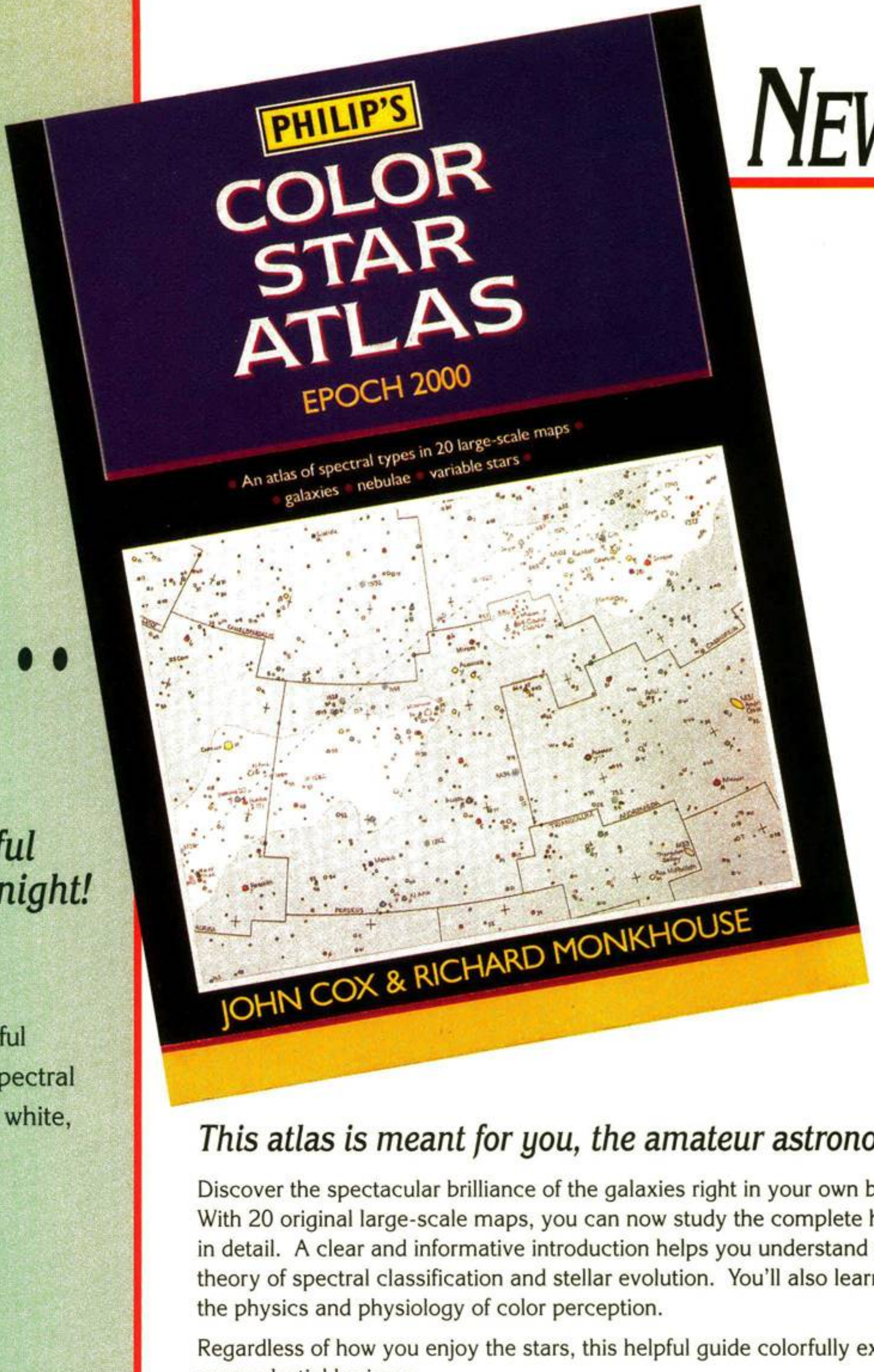
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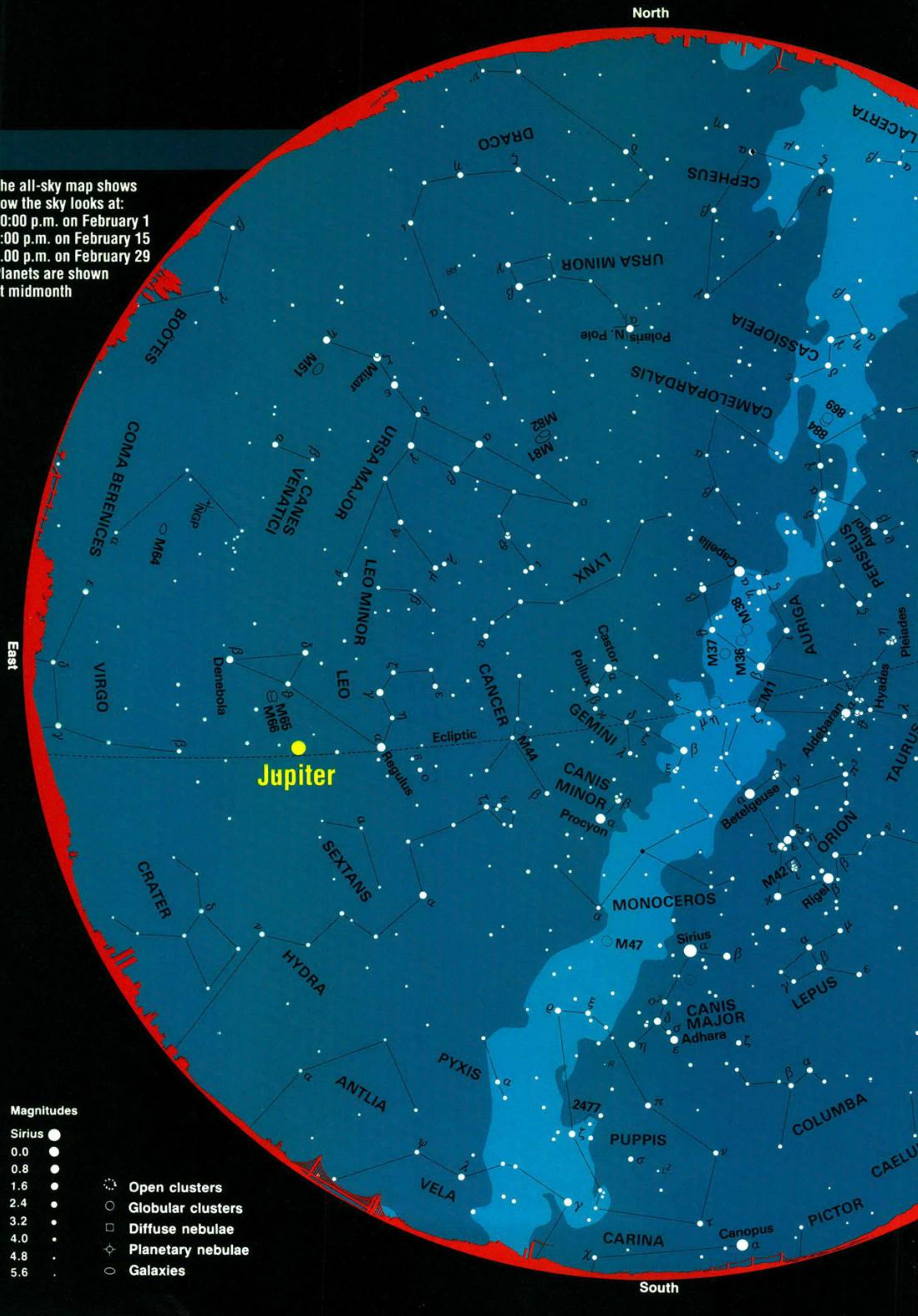
The all-sky map shows how the sky looks at:
10:00 p.m. on February 1
9:00 p.m. on February 15
8.00 p.m. on February 29
Planets are shown at midmonth


North
East
South
DRACO
CEPHEUS
LACERTA
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Polaris
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BOÖTES
M51
Mizar
M82
M81
869
884
URSA MAJOR
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M64
LYNX
Capella
PERSEUS
Algol
LEO MINOR
AURIGA
M38
M37
M36
Pleiades
Castor
Pollux
M1
Hyades
Aldebaran
TAURUS
VIRGO
Denebola
M65
M66
LEO
CANCER
GEMINI
Ecliptic
M44
Jupiter
Regulus
CANIS MINOR
Procyon
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ORION
M42
Rigel
SEXTANS
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M47
Sirius
HYDRA
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Adhara
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2477
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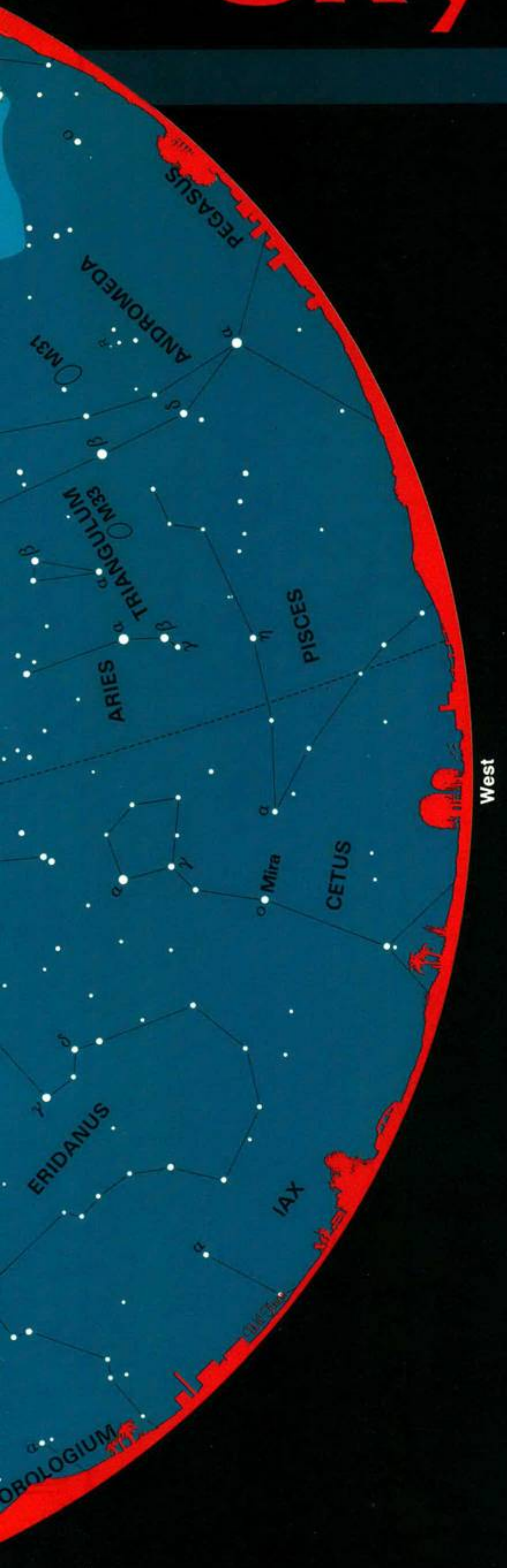
PICTOR
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

February 1992



A GATHERING IN THE MORNING

Watch for the splendid gathering of planets in the predawn sky during February. Venus and Mars steal the show for most of the month and then during the last week of February, Saturn emerges from the Sun's glare to join them. The waning crescent Moon pays two calls to the region: once on February 1 and again on the 29th.

VENUS PASSES MARS

Look for Venus and Mars close together on the morning of February 19, when they'll make an eyecatching pair. Notice how their colors differ, with brilliant white Venus contrasting with warm-tinted Mars.

JUPITER AT OPPOSITION

Jupiter lies opposite the Sun in the sky on February 29, Leap Day. This bright white object will become strikingly visible over houses and trees to the east about an hour after sunset. If you have a telescope, this largest of all the planets is a superb sight awaiting you.

Calendar of Events

1 Mars passes 1.5° south of Neptune, 3 a.m. EST

The Moon passes 0.9° north of Uranus, 4 a.m. EST

The Moon passes 0.03° south of Neptune, 5 a.m. EST

The Moon passes 1.5° north of Mars, 8 a.m. EST

2 The Moon is at apogee (252,593 miles from Earth), 4:50 a.m. EST

3 The Moon is New at 2:00 p.m. EST

7 Venus passes 0.9° north of Uranus, 2 a.m. EST

8 Venus passes 0.3° south of Neptune, 10 a.m. EST

11 First Quarter Moon is at 11:15 a.m. EST

12 Mercury is at superior conjunction

17 The Moon is at perigee (222,511 miles from Earth), 5:51 a.m. EST

18 The Moon is Full at 3:04 a.m. EST

19 Venus lies 0.9° north of Mars, 5 p.m. EST

25 Last Quarter Moon is at 2:56 a.m. EST

28 The Moon passes 1.2° north of Uranus, 1 p.m. EST

The Moon passes 0.2° south of Neptune, 4 p.m. EST

Jupiter is at opposition, 7 p.m. EST.

Venus lies 0.1° north of Saturn, 8 p.m. EST

29 The Moon is at apogee (252,225 miles from Earth), 3:53 p.m. EST

PLANETS BEFORE DAWN

Set your alarm clocks early! This month a fine dance of planets occurs low in the southeast before sunrise. Brilliant Venus shines like a beacon at magnitude –4.0. Ruddy Mars is also there, much fainter than Venus, at 1.3 magnitude; it lies lower in the predawn sky. On February 1, the waning crescent Moon lies only 1.5° from Mars. After that date, the Moon dives down into the dawn, and the two planets begin inching together, with Venus sinking and Mars rising higher.

VENUS, JUPITER, MARS, AND THE MOON gathered in the evening sky on June 15, 1991. A similar grouping, minus Jupiter, will occur in the morning sky this month. Photo by James Foster and Michael Stecker.

Both Venus and Mars stand among the stars of Sagittarius when February begins. You may be able to pick out the familiar stars of the Teapot asterism. As the month progresses, the Teapot will slide higher each morning, while the planets draw together. On February 19, the two planets lie just 0.9° apart. For several mornings, Venus and Mars are beautiful to see in a single binocular field of view. Venus is brilliant white, while Mars looks definitely reddish.

When Venus and Mars stand closest together, a third planet is rising out of the mists along the eastern horizon. Saturn (magnitude 0.7) ascends high enough in the predawn sky to be easily visible by the end of February, and Venus lies 0.1° north of it on the morning of February 29. That same morning Mars lies to the upper right less than 5° away. Higher still is the crescent Moon, poised to sweep down past the planets in March.

JUPITER COMES TO OPPOSITION

Jupiter rises in the east about two hours after sunset when February begins. It comes up earlier as the days pass, finally reaching opposition during the night of February 28/29. At opposition, the day on which Earth lies between the Sun and Jupiter, the planet rises at sunset, is highest in the sky around midnight, and sets at dawn. Jupiter is the biggest planet and one of the brightest objects in our sky. Around the time of opposition, it shines more brightly (–2.5 magnitude) than it has since its last opposition a year and a month ago. On the evening of February 18, you can see it ascend the eastern sky in the company of the Full Moon.

This year's opposition for Jupiter takes place in front of the constellation Leo. Jupiter intrudes on the Lion's stars and lies about 10° — the width of a palm at arm's length — away from Regulus, Leo's brightest star. (The name Regulus means "the little king," but the star is also commonly called the Heart of the Lion.)

If you have a pair of binoculars, turn them on Jupiter. You'll see one or more of the four large Galilean moons, so named because the famous Italian astronomer was the first to see them. From closest to farthest, they are named Io, Europa, Ganymede, and Callisto. The moons look like little stars lying close to Jupiter, and since they all orbit in the plane of Jupiter's equator, they appear in a line bisecting the planet. Notice how their positions change from night to night.

FEBRUARY'S PLANETS

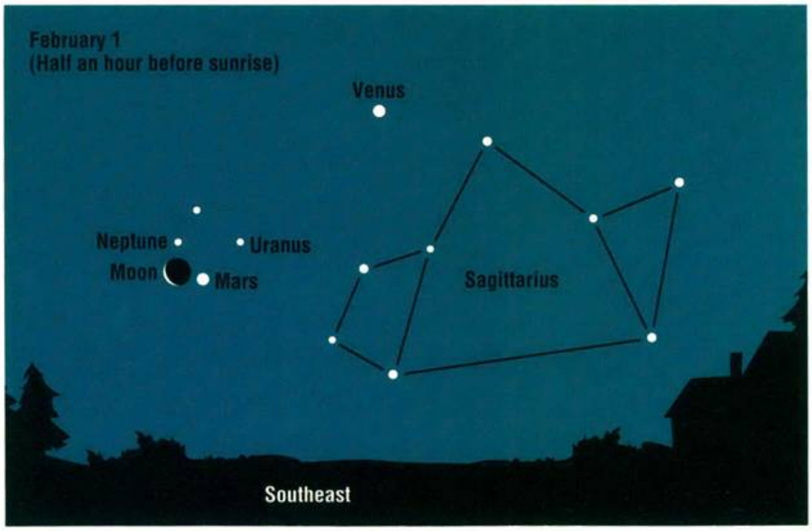
The evening sky is empty of planets for the first couple of hours after sunset when the month begins. Then the following planets rise in the order of mention.

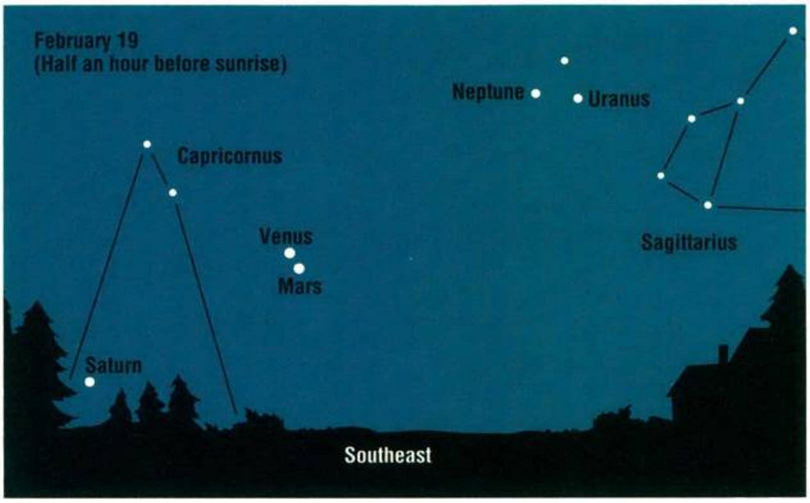
Jupiter, in Leo, sails over the eastern horizon in mid-evening early in the month. Each evening it comes up a bit earlier, finally rising at sunset on the night it lies opposite the Sun, February 28/29. All month it shines at its maximum brightness for the year: –2.5 magnitude. Look for the planet near the Full Moon on the night of February 18. And keep watching during the months ahead as Jupiter becomes conspicuous in the evening sky.

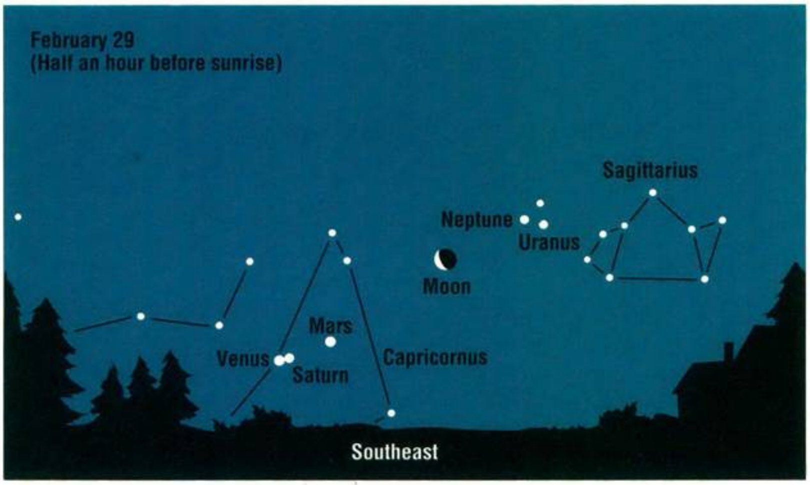
Venus rises about two hours before the Sun. Outshining everything except the Sun and Moon, it blazes at magnitude –4.0. Venus lies 0.9° north of Mars on February 19, and is 0.1° north of Saturn on the morning of February 29. Venus will linger in our predawn sky throughout the winter and spring.

Uranus and **Neptune**, both in Sagittarius, are in the predawn sky now. These objects are primarily telescopic, but Venus pays both a visit this month, making them easy to spot in binoculars. On February 7, Venus lies 0.9° north of 6th-magnitude Uranus. The following day, Venus lies south of 8th-magnitude Neptune, only 0.3° away.

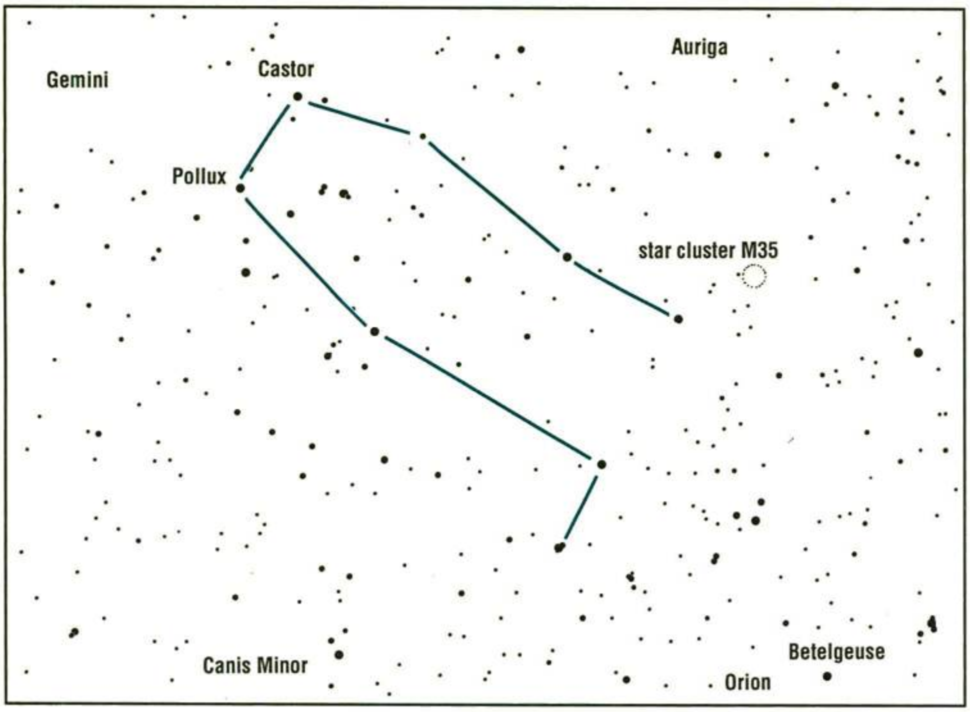
Mars is about 10° below and to the left of Venus when February begins. At magnitude 1.3, it is about 100 times fainter than Venus. On February 1, Mars lies 1.5° south of the Moon. By month's end the amber-colored planet has passed Venus and stands above it in the predawn sky. Mars will continue to appear faint for some months to come. As it slides eastward against the starry backdrop this year, Mars will traverse several constellation boundaries. In Sagittarius early in the month, Mars crosses into neighboring Capricornus in mid-February.


February 1
(Half an hour before sunrise)
Venus
Neptune
Uranus
Moon
Mars
Sagittarius
Southeast


February 19
(Half an hour before sunrise)
Neptune
Uranus
Capricornus
Venus
Mars
Sagittarius
Saturn
Southeast


February 29
(Half an hour before sunrise)
Sagittarius
Neptune
Uranus
Moon
Mars
Venus
Saturn
Capricornus
Southeast

Saturn emerges from the Sun's glare by month's end to appear as a faint light low in the southeastern predawn sky. Around the end of February, Saturn shines at magnitude 0.7. It makes a striking sight



near Venus for the mornings around February 28. Early in March Mars will overtake Saturn, when both are in Capricornus, the constellation that's "home" to Saturn all this year.

Mercury comes to superior conjunction with the Sun on February 12. This is the date when it lies directly on the other side of the Sun from us, and of course is hidden in the Sun's glare. But it'll return to view in the evening sky next month.

THE STARRY SKY

The evening skies of winter contain many bright stars, but two of the most conspicuous are Castor and Pollux in the constellation of Gemini the Twins. These two 1st-magnitude stars lie only 4.5° apart. They are the brightest stars in their constellation, where each represents the bright eye of a Gemini twin.

These stars have been tied to the idea of twins for so many thousands of years and by so many different cultures, that you might expect them to look alike. But Castor is noticeably fainter than Pollux, shining at magnitude 1.6 to Pollux's 1.1. Also Castor is white, while Pollux is distinctly golden. We now know the two are also located at different distances from Earth, with Castor being 49 light-years away and Pollux 35 light-years.

Castor may be fainter, but it's the more interesting star. A small telescope shows it as two separate stars, with a third component nearby. And each of the three is also a double star, so the single point of light we call Castor is really *six* stars in all.

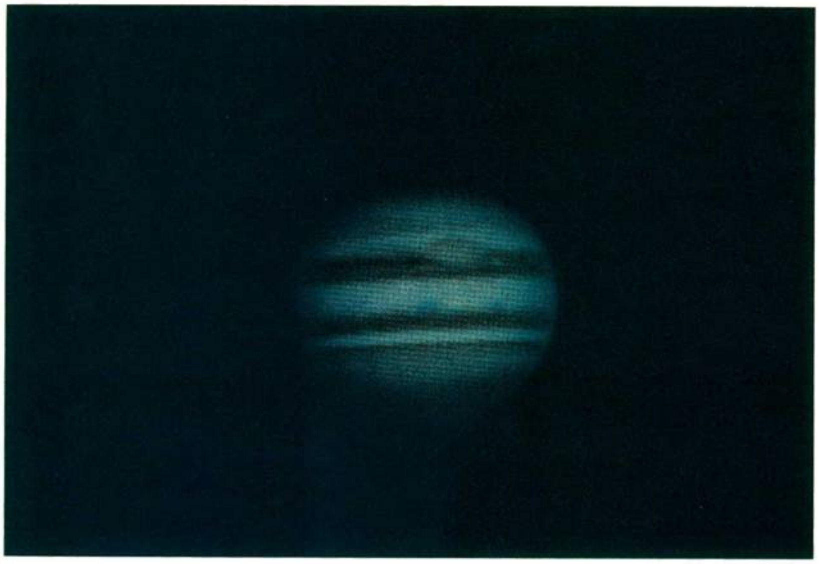
To the Greeks, Castor and Pollux were the Dioscouri, or "sons of god." In Greek mythology, they were said to be the offspring of Zeus and Leda, who was the mortal wife of King Tyndareus. In the story, Zeus (disguised as a swan) ravished Leda. Afterward, she gave birth to two eggs. From one hatched two mortal twins, Castor and Clytemnestra. From the other hatched two immortals, Pollux and Helen.

The two brothers were identical and inseparable. As they grew, Castor developed skill with horses. He became a famous charioteer, while Pollux became a boxer. In legend, the two brothers shared many adventures. They were among the Argonauts who sailed with Jason in search of the Golden Fleece. It was said that after a great storm, two fiery lights appeared over the ship, one above the head of each twin. Thereafter Greek and Roman mariners considered the twins to be "a welcome couple to a vexed barge." Sometimes they were symbolized by two stars over a stylized ship. At other times, ships carried images of Castor and Pollux on their bows to ward off shipwreck.

It's said that when Castor was killed in an argument, Zeus offered Pollux his birthright immortality. But Pollux refused to live without his brother. This display of brotherly love was rewarded when Zeus placed both twins in the sky. □

Deborah Byrd is writer, coproducer, and cohost of the nationally syndicated radio series "Earth and Sky."

THE MAIN EVENT: JUPITER AT OPPOSITION



JUPITER, KING OF THE PLANETS, moves into the evening sky on the last day of February. It will be an excellent target for telescopes this winter and spring. Jean Dragesco photo.

Jupiter reaches opposition on February 29 at 1h universal time. (This translates to the evening of the 28th in civil time in North America.) The planet is a –2.5-magnitude object in southern Leo the Lion, easily spotted as the brightest object in that part of the sky.

During February Jupiter spans an apparent angular diameter of about 44". This large disk makes it easier for you to see the dark belts and bright zones of its cloudy atmosphere in even a small telescope. The photo at right shows the main features you can expect to see. First-time viewers often have trouble seeing much more than the north and south equatorial belts. But nearly everyone finds that they can see much more after viewing the planet each evening for a week.

Jupiter's declination this month is about +9°, which gives telescopic observers in the Northern Hemisphere the opportunity to view the planet for over 12 hours. If you subtract some of that time to allow for poor seeing when the planet lies near the horizon as it rises and sets, you still end up with about 10 continuous hours to view Jupiter. As it happens, this is the same time it takes Old Jove to spin once on its axis: 9h55m. The result is that in the course of a single night you can follow Jupiter through one entire rotation.

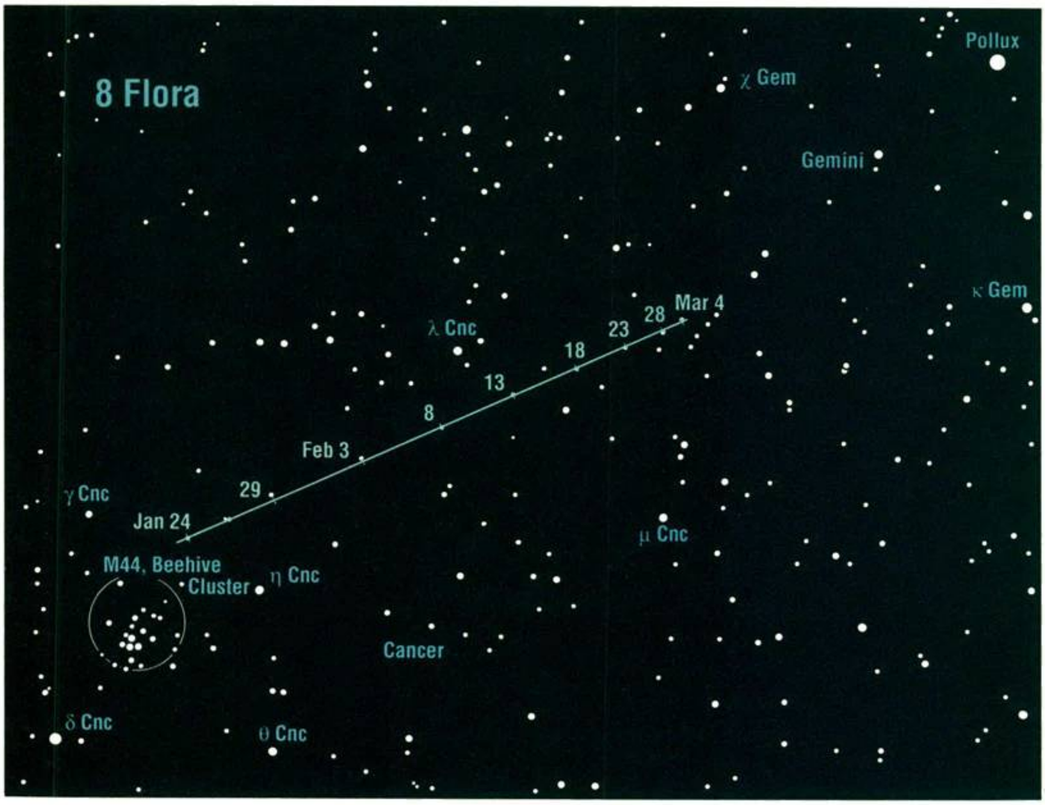
How can you take advantage of this? One way is to plan an "all-nighter" and check in on Jupiter visually about once an hour. This will give you a series of mental snapshots of the planet's changing face. (If you have never done this, expect to be surprised by how much its appearance changes each time you look.)

Or for a more permanent record, consider making a sequence of disk drawings or sketches. These don't have to be very elaborate — and if you make them all the same size on separate pieces of paper, you could assemble a flip movie out of your night's work. A third possibility is to make a strip-drawing. This is actually easier than the individual views and usually results in more details being recorded. It works like this:

The center of Jupiter's disk always displays the most detail, so that's the section to try to capture in your hourly sketches. In one hour, Jupiter rotates 36° and this means you should try to capture the middle third of its disk every hour to keep up with its rotation.

Try the following technique. Lightly draw with a ruler two parallel lines 1.5 inches apart and extending for 5 inches. This provides an "unwrapped" blank Jupiter. Shade the entire strip lightly and smoothly with a blunt #2 pencil, and smear the shading with a tissue into an even light gray.

Each hour during the night, go outside and observe Jupiter. Use a red-lensed flashlight to save your night vision. Starting at the left-hand edge of the unwrapped Jupiter, draw in the darker features (the belts), again smudging as needed. Then erase the light-gray shading as necessary to show the white features. Work quickly — strive to complete each section in 10 minutes or less. Then, when the next hour begins, pick up where you left off and get down the new parts of Jupiter that have rotated onto the center of the disk. Continue doing

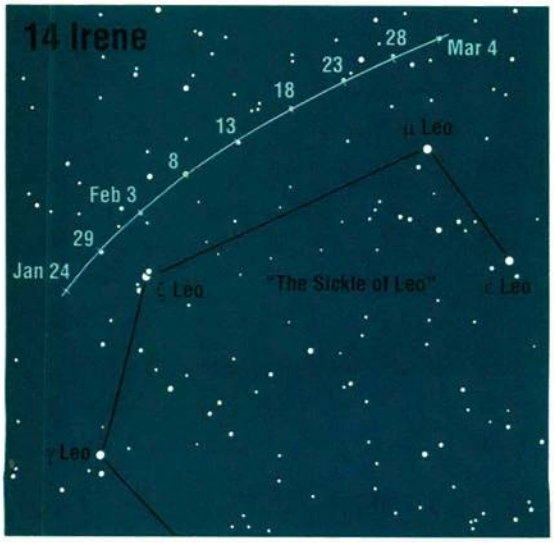


this throughout the night — or as late as you can stand. With each section you complete, note the time when you began and finished. Then, when you finish for the night, note the date and times and the magnification and instrument you used.

I recommend you start with just the three shades, but you'll soon become proficient in gauging and using middle tones as well. Avoid color renditions until you feel comfortable with the process. And in any case, it's better not to try to use color at the eyepiece. Rather, do a black-and-white drawing at the telescope and later insert the colors — pencils, pastels, or watercolor — based on notes you take while observing.

COORDINATES FOR FLORA

Date	R.A. (2000)	Dec.
Jan. 24	8h37.8m	21°13'
Jan. 29	8h32.2m	21°50'
Feb. 3	8h26.7m	22°25'
Feb. 8	8h21.6m	22°56'
Feb. 13	8h17.0m	23°23'
Feb. 18	8h13.1m	23°45'
Feb. 23	8h10.0m	24°04'
Feb. 28	8h07.7m	24°17'
Mar. 4	8h06.4m	24°27'



TELESCOPIC PLANETS

Mercury is all but invisible until late February. It begins its climb out of the western horizon on February 23, on its way to a decent evening appearance next month. (You might find it an enjoyable challenge to see what the earliest date in late February is that you can spot it. Start searching half an hour after sunset and look low in the west.)

Venus dominates the morning sky in February as it blazes at magnitude –4.0 early in the month and then drops imperceptibly to –3.9 magnitude for the rest of February. Your telescope will show you a 12"-diameter gibbous disk. In viewing Venus, take a tip from a longtime observer. Because sunlight reflects so brightly from Venus' white clouds, it has the tendency to dazzle your eye when you view during full darkness. For this reason you may find the planet easier to observe after morning twilight has begun. This lightens the sky around the planet and reduces the glaring contrast.

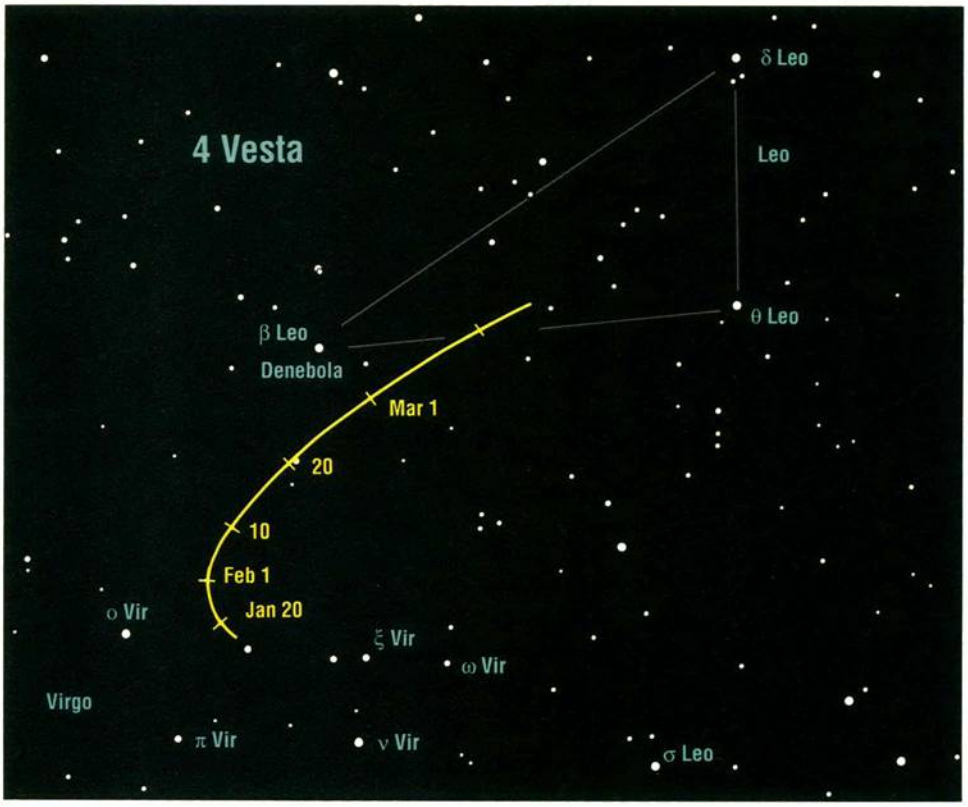
Venus has conjunctions with many objects during February. On the 7th, it passes 0.9° north of Uranus and on the next day comes even closer to Neptune, passing only 0.3° south of it. Venus then waits until the 19th, when it passes 0.9° north of Mars, and finishes off the month by passing just 0.1° north of Saturn on Leap Day (the 29th).

The white clouds of Venus reflect sunlight almost perfectly, so the white we see looking at Venus is a good match for pure sunlight. As Venus makes its tour of the other four planets, you have a rare opportunity to compare their colors against this pure white.

This will reveal to you the differences between the pale green color — like weak pea soup — of **Uranus**' 3.5"-diameter disk and the light blue displayed by **Neptune**'s disk, 2.2" across. Ten magnitudes of brightness separate Venus and Uranus, and 12 magnitudes lie between Venus and Neptune. To see the contrast most clearly, use the highest magnification that places them both in the same field of view. (You could also hold a weak neutral density filter over the eyepiece when viewing Venus and remove it when looking at Uranus or Neptune.)

The color contrast between Venus and **Mars** is more interesting than that between Uranus and Neptune. The warm ruddy color of the Martian deserts makes a strong counterpoint to the white clouds of Venus. Mars' 1.3-magnitude disk is a lot brighter than Uranus or Neptune, but its 4.2"-diameter disk won't appear much bigger and you shouldn't expect to see more than faint markings on it.

The conjunction between Venus and **Saturn** should be exquisite. However, you'll need to pick a viewing site with a good view to the southeast, because both objects are quite low. Saturn is at magnitude 0.7, and its rings span a distance of 35". This is a pair you can follow with your telescope past sunrise. Don't be surpised if you find that seeing gets better around the time the Sun rises and stays that way for a while thereafter. Enjoy the contrast of the pure white Venus with the subtle tans and browns of Saturn and its rings. I know I will.



ASTEROIDS IN THE EYEPIECE

February provides a trio of asteroids for your viewing pleasure. Asteroid 8 **Flora** is a carryover from last month, when it reached opposition to the Sun on January 26. It is a 9th-magnitude dot moving northwestward in Cancer about halfway between the Beehive Cluster and the star Pollux in Gemini (see the map opposite).

The second asteroid this month is 14 **Irene**, which reaches opposition on February 14. Moving northwestward just above the Sickle of Leo (see the map opposite), Irene is a 9th-magnitude point of light.

Being faint, Irene and Flora may challenge you to find them, but 4 **Vesta** is a lot easier to spot. Although it doesn't reach opposition until next month, Vesta is so bright (a bit over 6th magnitude) that you can easily find it this month. Then you can follow it right through opposition into the evening sky as it curves through the hindquarters of Leo (see the map on this page).

To identify an asteroid, locate the star field it is traversing on the date in question, and then view the field with low-to-medium power. Map the stars you see (by hand or camera) and check the field again the next night. When you find the "star" that's moved, you've found it. ☐

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses mission, a spacecraft that encounters Jupiter this month before heading ultimately to the Sun.

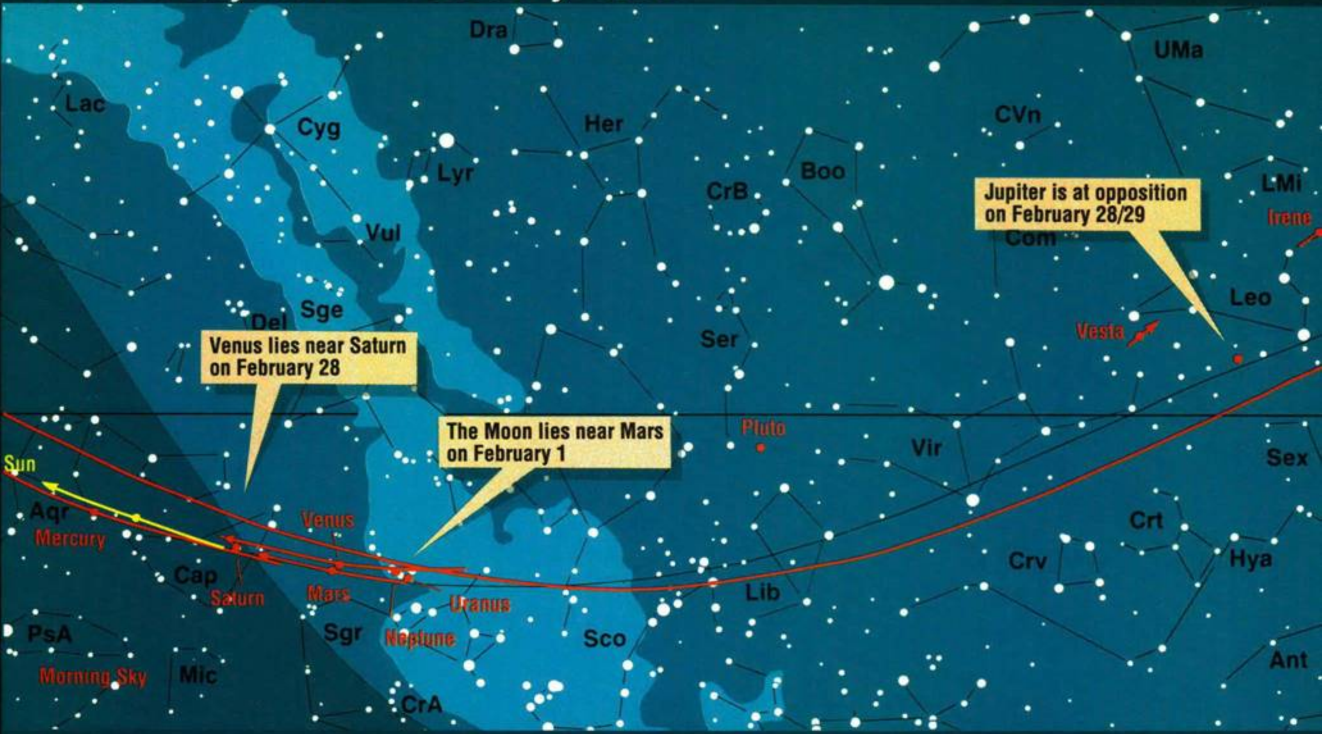
COORDINATES FOR VESTA

Date	R.A. (2000)	Dec.
Jan. 24	11h58.1m	9°09'
Jan. 29	11h58.5m	9°33'
Feb. 3	11h58.3m	10°01'
Feb. 8	11h57.3m	10°34'
Feb. 13	11h55.6m	11°11'
Feb. 18	11h53.1m	11°51'
Feb. 23	11h50.0m	12°34'
Feb. 28	11h46.3m	13°17'
Mar. 4	11h42.2m	14°00'

COORDINATES FOR IRENE

Date	R.A. (2000)	Dec.
Jan. 24	10h24.4m	23°04'
Jan. 29	10h20.7m	23°50'
Feb. 3	10h17.5m	24°38'
Feb. 8	10h13.6m	25°24'
Feb. 13	10h09.3m	26°08'
Feb. 18	10h04.8m	26°48'
Feb. 23	10h00.2m	27°22'
Feb. 28	9h55.7m	27°50'
Mar. 4	9h51.6m	28°11'

The Solar System February 1992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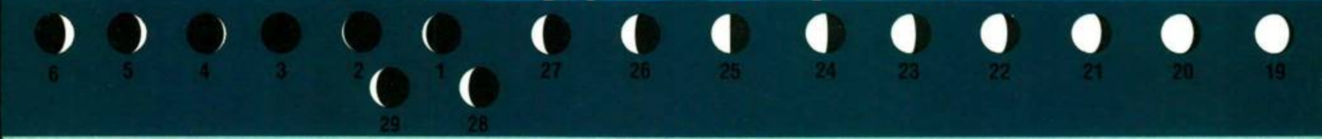
Vesta
Pluto
Vir
Sex
Sun
Aqr
Mercury
Venus
Crt
Cap
Hya
Crv
Saturn
Mars
Uranus
Lib
PsA
Sgr
Neptune
Sco
Ant
Morning Sky
Mic
CrA

Venus lies near Saturn on February 28

The Moon lies near Mars on February 1

Jupiter is at opposition on February 28/29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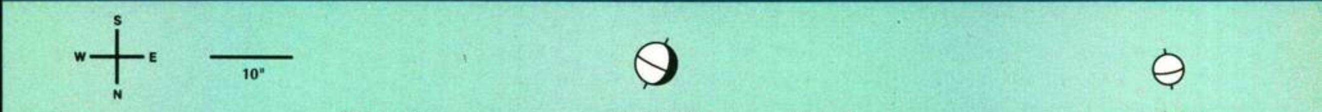
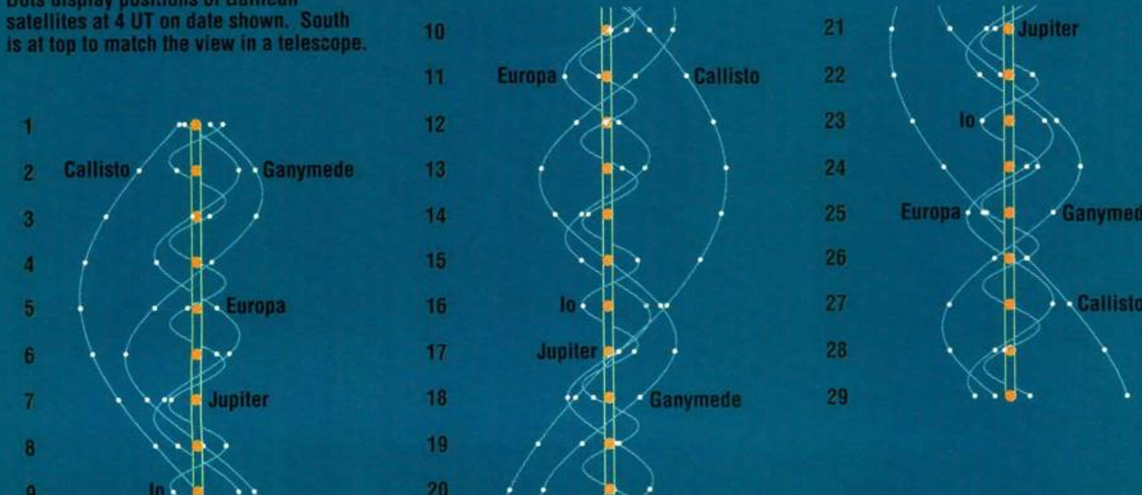


Planet	MERCURY	MERCURY	VENUS	MARS
Date	February 1	February 29	February 15	February 15
Magnitude	–0.8	–1.2	–4.0	1.3
Angular Size	4.8"	5.7"	12.0"	4.2"
Illumination	98%	83%	86%	97%
Distance (AU) from Earth	1.406	1.174	1.385	2.233
Distance (AU) from Sun	0.452	0.318	0.726	1.438
Right Ascension (2000.0)	20h25.4m	23h36.8m	19h50.1m	19h59.8m
Declination (2000.0)	–21°12'	–2°45'	–20°54'	–21°31'

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.



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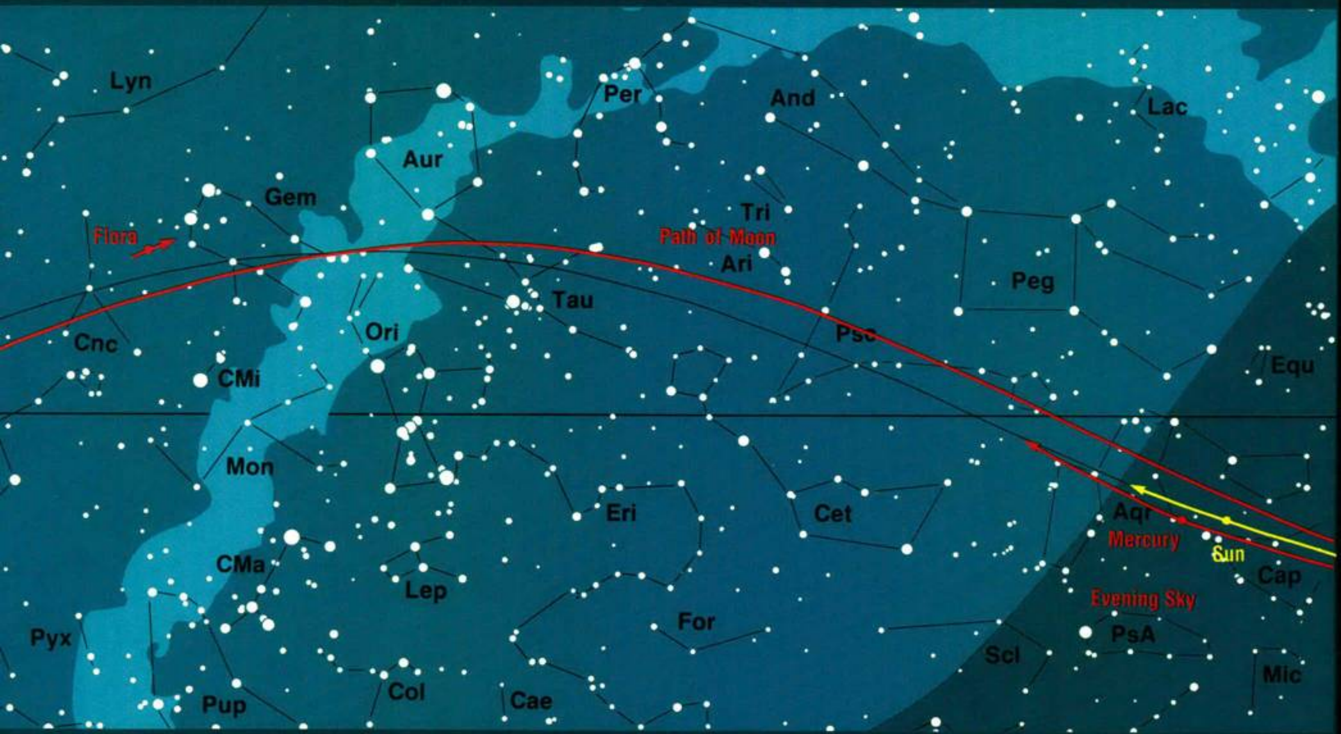
Lyn
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Tri
Flora
Path of Moon
Ari
Peg
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Cnc
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Eri
Cet
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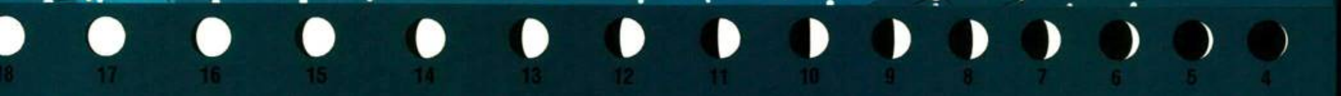
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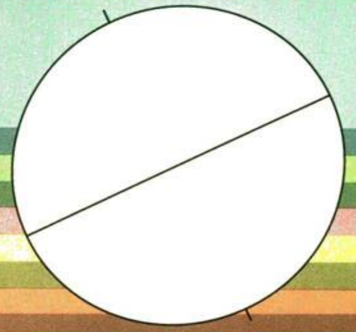
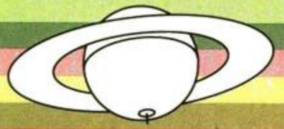
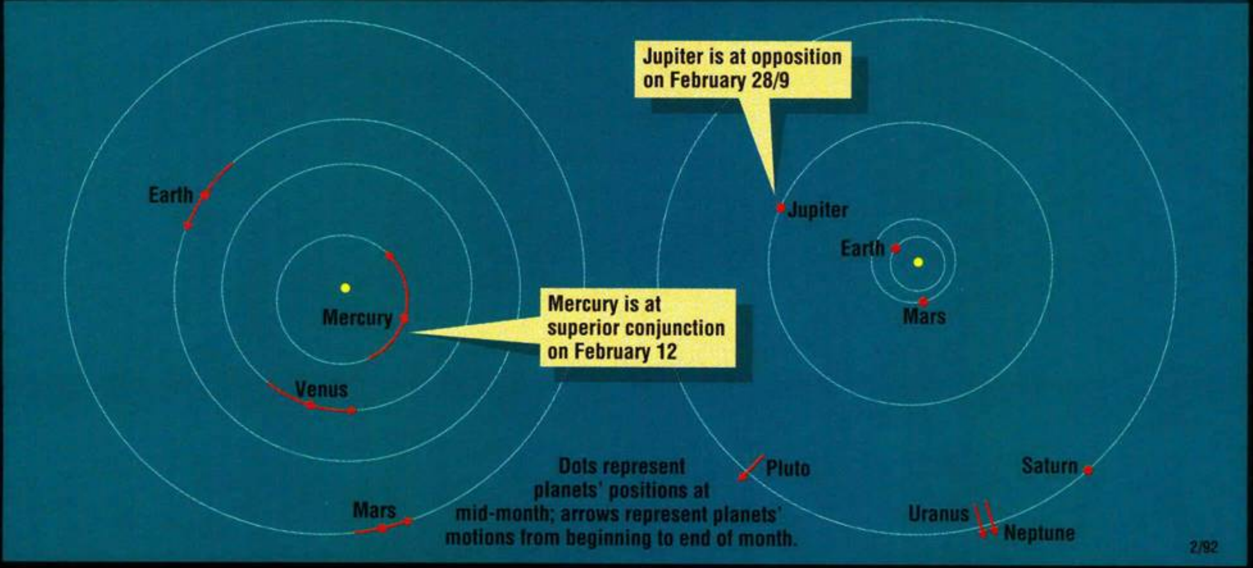




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15
−2.5	0.7	5.8	8.0	13.7
44.3"	15.2"	3.5"	2.2"	0.1"
100%	100%	100%	100%	100%
4.443	10.882	20.271	30.969	29.631
5.399	9.928	19.517	30.194	29.691
10h54.2m	20h55.7m	19h11.1m	19h17.5m	15h37.4m
8°28'	−18°00'	−22°49'	−21°31'	−4°07'

The Planets in Their Orbits

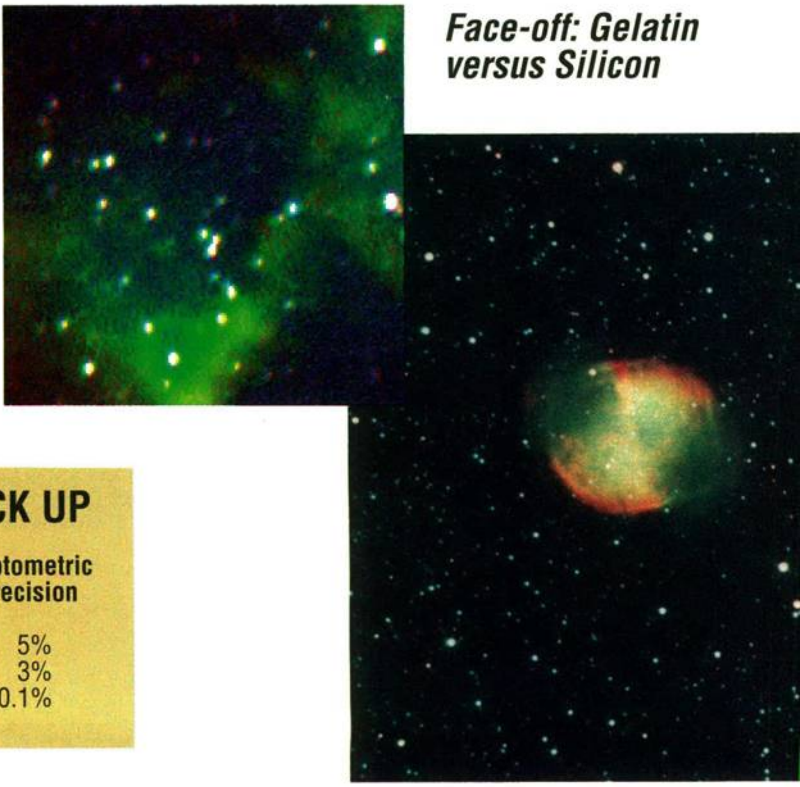

Earth
Mercury
Venus
Mars
Jupiter
Earth
Mars
Pluto
Saturn
Uranus
Neptune

Jupiter is at opposition on February 28/9

Mercury is at superior conjunction on February 12

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

SONOPTOR f=15mm 1:1.6
SONY
Nickel Cadmium
REPLACEMENT
BATTERY
RB 22
VDO-PAK
36
RVP
135
FUJIC
35 mm Film
for Color Slides
400
DX



Face-off: Gelatin versus Silicon

HOW FILM, VIDEO, AND CCDS STACK UP

Imaging Technology	Number of Pixels	ISO Speed	Photometric Precision
Film	1,000,000	400	5%
Video	200,000	1000	3%
CCD still	50,000	100	0.1%

CELESTIAL SEEING:
Three Imaging Technologies

Film, video, and CCD — all three are a part of modern amateur astronomy, each with its strengths and weaknesses.

by Richard Berry

Never before have amateur astronomers had so many options for viewing the universe. In the distant past, all observing was direct — if you were an astronomer, you gazed through the eyepiece and drew what you saw.

By the 1920s, all that had changed. Twentieth-century technology made research by direct observing obsolete; photography took over from the eye. The planet Pluto was discovered on photographic plates, as were the nature of galaxies and the expansion of the universe. Photography saw fainter stars and deeper galaxies than the eye could ever see.

The '60s and '70s brought new types of indirect observing, technologies that allowed the astronomer to observe at a distance. Ultrasensitive television and image tubes invaded observatories, and by the middle of the '80s, many astronomers observed the heavens from warm rooms, on TV screens, in search of ever-fainter and more distant celestial objects.

35MM FILM IS HUGE compared with a CCD chip. A frame of 35mm film is 24 by 36 millimeters, but a CCD chip is only 2.5 millimeters on a side. VR1000 film photo and tricolor SBIG ST4 CCD image of M27 by Jack Newton.

Today, three imaging technologies contend for the amateur astronomer's attention. The first is photography, bolstered by enormous strides in making finer-grained films with high sharpness and vivid color. The second is video technology. Every few months you see newer, lighter, more sensitive camcorders enter the market. The third technology is the CCD still camera, the same technology professional astronomers are using to scan the outer edges of the universe.

This story is a survey of these three technologies and what they mean for amateur astronomy. First, we'll look at each method of indirect observation and explore the strengths and weaknesses of each. Then we'll explore the wide range of possibilities these technologies open to amateur astronomers.

Photography: Best for Big Fields

Today's color and black-and-white films are fantastic compared with the best films available a decade or two ago. The new films are finer-grained and faster because photographic scientists came up with a new way to make photographic emulsions.

When light strikes a silver halide crystal in a photographic emulsion, the crystal becomes developable to metallic silver grains. Back in the '60s, the thinking went: Big crystals would develop into big metallic silver grains, bigger grains would make the negative black, and black negatives meant speed. Thus pre-'60s films were very fast and very grainy.

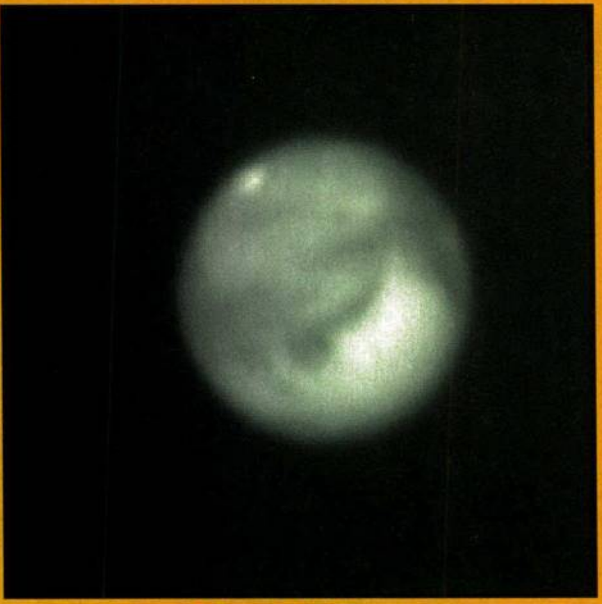
The fly in the photographic ointment was that big-grain films weren't very efficient. To form one exposed film grain, between fifty and one hundred photons had to strike the film — an efficiency of only 1 or 2 percent.

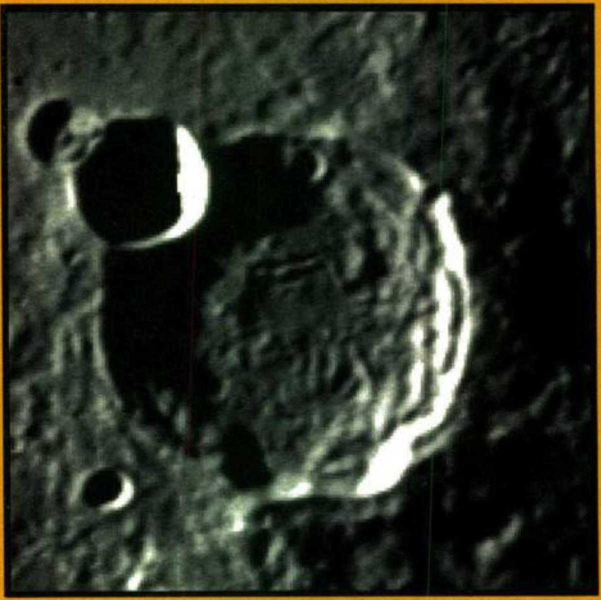
Improved emulsions began with a fundamental change in thinking. Instead of trying to make silver halide crystals bigger, the scientists made the crystals more efficient. Instead of big round ones, they created small, flat, and very uniform crystals of silver halide. Because they were tablet-shaped, the crystals presented the same light-sensitive surface as round grains, and because they were small, more crystals fit in the same space. With tablet grains (T-grains), film efficiencies rose to nearly 5 percent.

Although the new emulsions were more efficient, they needed longer exposures for faint objects. When astronomers applied the new films to celestial photography, they had to expose twice as long, but they recorded stars four times fainter.

At this point, an older technology called hypersensitizing proved itself valuable. In making film, manufacturers must choose between reciprocity failure and product shelf life. By exposing film to hydrogen in a heated container, the silver halide crystals in a photographic

Face-off: Video CCD vs. CCD Still


Video CCD Frame


Still CCD Frame

THE BEST VIDEO AND THE BEST STILLS can be comparable in quality for bright targets. The greatest difference lies in how precisely the brightness in the image follows that of the original scene. Video image by Roy Tucker; CCD image by Don Parker.

emulsion become primed for exposure. When you take a picture with hypered film, it responds with even higher efficiency.

Today's astrophotographer can choose among off-the-shelf print-film speed champs like Konica 3200 and Ektar 1000 or select a slower, fine-grained film like Fuji HG400 or Ektar 125 for rich, saturated color. All of these films use T-grain technology or something akin to it. Slide films such as Scotch Chrome 400, Kodachrome 200, and Fujichrome RD100 excel with rich color and good grain. Although their ISO speed ratings are modest, when these films are hydrogen-hypered they deliver rich, true color with short exposure times.

Among the black-and-white films, hypered Tech Pan 2415 stands head and shoulders above the others with its combination of fine grain and high sensitivity. T-Max P3200 excels as a film for fast recording of faint light, and T-Max 400 has replaced "old faithful" Tri-X as the all-around emulsion for casual black-and-white astrophotography.

Compared with video and CCD cameras, photographic films have several disadvantages. It is difficult to *measure* the amount of light that has fallen on film because the relationship between light and film density is not linear. With color films, nonlinearity translates into underexposed pictures that look green or brown.

Another disadvantage is that photographs have to be developed and printed before you can view them. If you're trying to get the very best pictures possible, the delay between taking a picture and seeing the result makes improvement difficult. Instant cameras offer partial relief, but instant films simply don't compare with conventional films for speed or quality.

Despite its limitations, however, photography is tops for many astronomical applications. You can shoot film anywhere and anytime — no electricity required. But perhaps film's biggest advantage is its format.

Film is enormous compared to video and CCD detectors. A single frame of 35mm film has 25 times the area of typical video camera chips and 150 times the area of the chip most commonly used in CCD still cameras. For wide-field deep-sky images, it's just about impossible to beat film.

Video: Reality Captured

Video, too, has come of age for astronomy. Techniques as simple as pointing an ordinary camcorder into the eyepiece give sharp views of the Moon and planets. Serious astrovideographers prefer compact, closed-circuit television cameras for their forays into high-resolution video. The great strength of video is that a good tape shows more detail than you see through the eyepiece; the down side is that what you see on the monitor is what you've got. Video stills look soft compared with the moving tape.

But the many fine tapes we received at ASTRONOMY following the July 11 eclipse convinced us of the power of the medium. Seeing a tape isn't experiencing the real thing, but it's the next best thing. Although it's impossible to reproduce the effect of live video in the pages of a magazine, it's utterly wonderful to see the Moon, the planets, or the Sun on your television looking as good as they ever appear in a high-power eyepiece.

Today's video cameras almost all use solid-state CCD chips to sense light. Even though CCDs are extremely sensitive to light, the longest exposure a video camera makes is $\frac{1}{30}$ of a second — so they do not operate well in extremely dim light. At low light levels, the video image becomes coarse and grainy. The Moon, the planets, and bright stars record well, but only a few nebulae shine strongly enough for video.

A number of firms offer compact closed-circuit video cameras with external gain adjustment controls. Prices begin around $400. Used with eyepiece projection, such cameras are ideal for real-time lunar and planetary imaging, as well as for spendid time-lapse hydrogen-alpha videos of solar prominences.

There is even an attractively priced video system for under $300. The camera uses a very small CCD chip at the standard 30-per-second video frame rate to freeze atmospheric seeing. Despite the common notion that "more pixels are better," the system achieves diffraction-limited imaging by keeping the number of pixels small and the exposure times very short. You view the image with a small video monitor beside the telescope.

In most video systems, the electrical signal goes onto videotape where the image is stored as an analog signal. When the output of a video camera goes directly to a digital frame grabber card installed in your computer, however, the results are impressive. Just as a digital recording on a compact disc sounds better than on an analog tape, the direct digital images are cleaner and sharper. During the 1988 apparition of Mars, Roy Tucker and Eric Craine of Western Research Co. used a dual-channel digital "frame grabber" board to capture outstanding images.

As desirable as digital frame grabbing may be, no still image can match the immediacy and emotional impact of a real, moving video image, and that's what video delivers.

CCD: Precision Images for Everyone

In the last decade, CCDs have swept the world of professional astronomy, and they are now rapidly gaining popularity with amateurs. Even though many video cameras have chips, CCD still cameras use the CCD chip very differently. In CCD still cameras made for astronomy, the chip is cooled and you can expose a single picture for up to an hour.

CCD cameras offer three big features: high efficiency, linearity, and digital output. This means that you can take pictures using exposures that are short compared with those used in conventional photography, and you can enhance the raw image with a computer to see more in your picture.

The down side of present-day CCD cameras is that the sensing area on the chip is small, and it's sometimes difficult to operate a computer at a remote observing site or even in a small observatory. A number of firms are developing flip-mirror finders for these cameras. In short, the companies in the CCD and telescope accessories fields aim to make using a CCD as easy as possible.

The reason that CCDs have suddenly become the topic of so much talk is that CCDs convert up to 60 percent of the light that strikes them into useful signal — and they have extremely good photometric properties. That means that a CCD image is a nearly exact record of how much light struck the CCD chip. With good observing techniques, you can pinpoint the brightness of a star or a cloudbelt on Saturn to about 1 part in 1000, or about twenty times better than you can with photography.

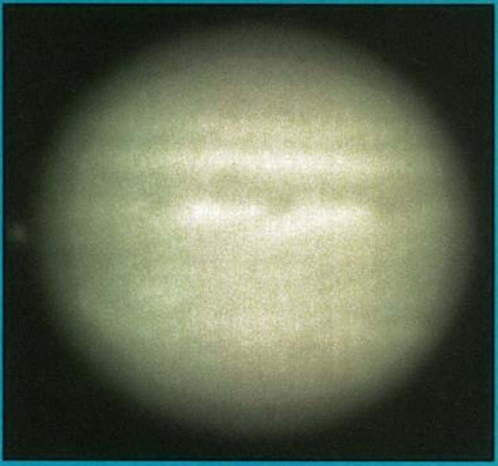
However, there's a price: you must shoot more than one frame to get a good picture. In addition to an image frame, for deep-sky images, you must shoot a dark frame and, for rigorously perfect images, also shoot a bias frame. For high precision, there's also the flat-field frame to shoot. These extra frames allow you to correct for minor flaws in the CCD and camera electronics.

Although the camera software does most of the work, the observer needs to stay alert to do the job right — and that's not always easy when you're observing after midnight. Once you've done the job, however, you have a meticulous record of the light from a celestial object.

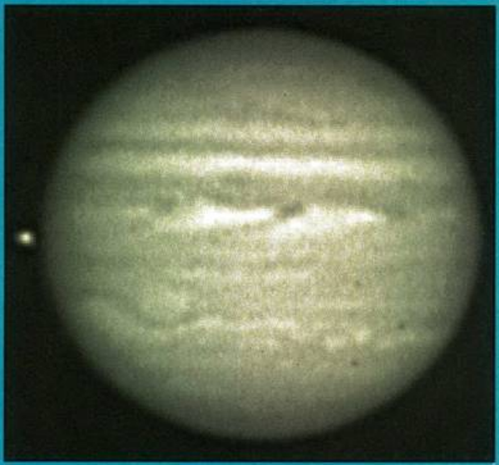
Because present-day CCD chips are small, CCDs capture a far smaller chunk of the sky than photographs. The popular TC-211 chip used in the Lynxx, SBIG ST4, and Electrim EDC-1000 cameras is a mere 0.1 inches on a side, so the area of the chip is $^{1}/_{150}$ that of a 35mm film frame! No wonder it's sometimes tough to find and center objects with a CCD camera.

Meanwhile, bigger CCDs are on the way. SBIG's new ST6 camera has a chip six times bigger than the chip in the ST4, and SpectraSource has a camera that's 30 times bigger, with a million pixels. That's

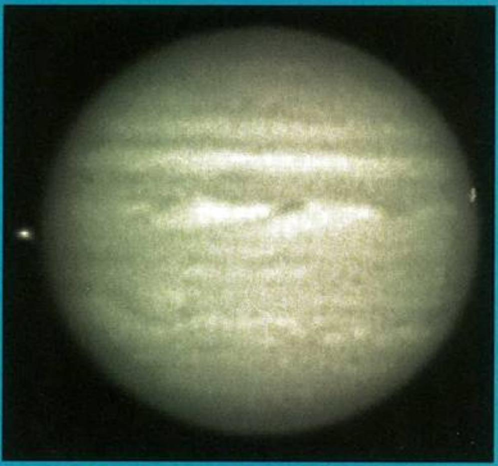
Image Processing to the Max



Raw Frame

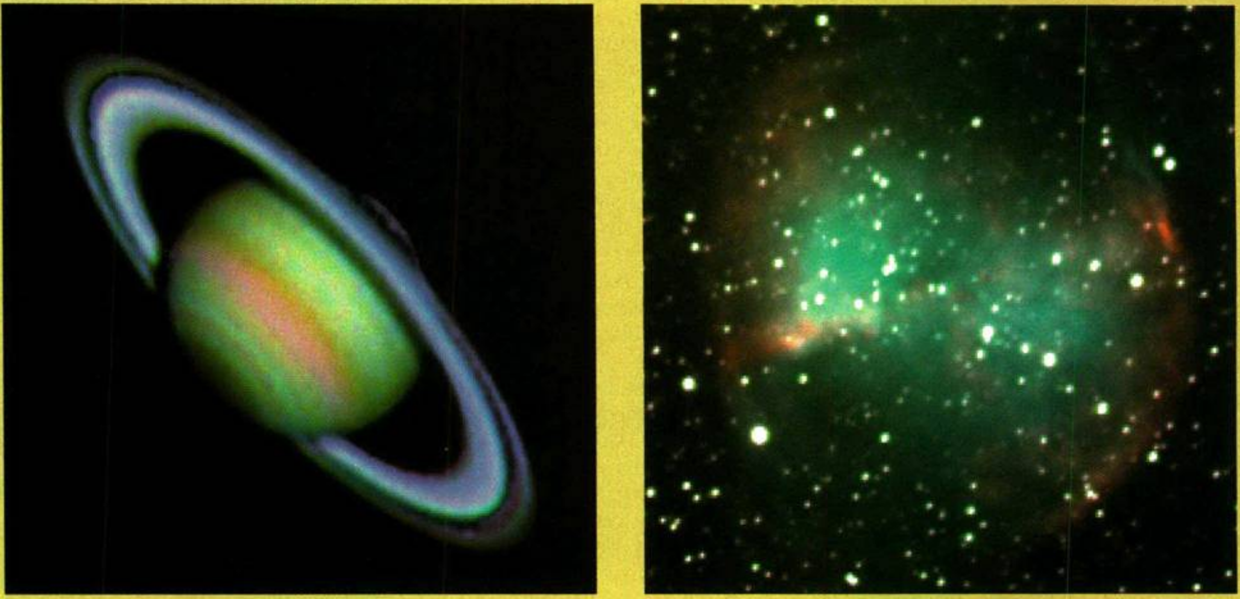


Conventional Processing



Maximum Entropy Processing

DIGITAL MAGIC TRANSFORMS JUPITER into a sharper image. The middle picture was optimized using computer unsharp-masking and sharpening, and the bottom picture by maximum entropy processing. Original image by Don Parker; maximum entropy processing by Ajai Sehgul, DSPS, Inc.



Planetary Color

Deep-Sky Color

SHOOT THREE FRAMES THROUGH COLOR FILTERS and then combine them for digital color. Don Parker shot the tricolor Saturn with a SpectraSource Lynxx on his 16-inch reflector, and Jack Newton took the tricolor picture of M27 with a prototype SBIG ST6 camera on his 25-inch reflector.

not to say the present generation of CCDs is too small to make useful observations. The TC-211 chip in the Lynxx, ST4, and Electrim is nearly perfect for recording planetary detail with telescopes from 8 to 16 inches aperture. At the optimum focal ratio between f/20 and f/40, Jupiter and Saturn each span the frame, Mars fills half the frame, and Venus, Mercury, and fainter planets can be imaged to the diffraction limit of the telescope with high photometric precision.

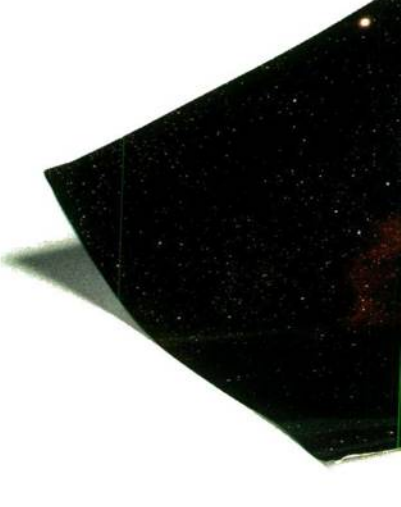
The precise image from a CCD is just the starting point in CCD imaging — with the right computer software, the observer can make the image brighter, dimmer, fuzzier, or sharper. It's even possible to give the dim parts of the image lots of contrast and make the bright parts of the image very flat so that you can see the faint outer parts of a galaxy as well as its bright nucleus. As a result, computer-processed CCD images often capture the visual appearance of a celestial object better than film does.

Much as a night in the photographic darkroom usually followed a night of astrophotography, an evening of image-processing follows a night of CCD imaging. The observer can call up each image and bring out the detail hidden in the image. With deep-sky images, it's like having a magic darkroom. For planetary images, you search for those few extraordinary images you took during moments of perfect seeing, and your reward — if you're lucky — is seeing the planet better than you could through the eyepiece.

One recent development is color CCD imaging. Planetary photographer Don Parker and deep-sky photographer Jack Newton have taken CCD images through red, green, and blue color filters, processed them with AstroIP software, and then combined the separate images into color pictures using another program, Aldus PhotoStyler. Examples of their color work appear in this story.

Finally, with a sophisticated image-processing technique called maximum entropy deconvolution, observers can expect amazing results. Maximum entropy software treats the raw image as the product of a perfect image and imperfections introduced by the telescope optics and the atmosphere, and seeks to remove the imperfections. Maximum entropy works with a special constraint: it does not create features that were not present in the original perfect image.

Radio astronomers have used maximum entropy for years to make radio "pictures" of the sky, and optical astronomers have become seriously interested because it offers a way to restore images from the optically flawed Hubble Space Telescope. Although most



maximum entropy software is written for mainframes or super-minicomputers, maximum entropy is finally coming to the PC.

As an example, a maximum entropy program from Digital Signal Processing Software, Inc. can process a 256-by-256-pixel image in five minutes on a 80486-based PC, a truly remarkable feat. This software can handle images from the SpectraSource Lynxx and SBIG ST4 cameras, as well as any image in the FITS file format.

With the same type of powerful software routines in their hands that professional astronomers use to clean up images from the Hubble Space Telescope, amateur astronomers can now extract every ounce of imaging performance their telescopes can deliver.

Take Your Pick or Pick All Three

The current revolution in astronomical imaging is hardly a revolution at all; rather, we're seeing the introduction of new technologies that complement rather than supplant older imaging systems. Traditional astrophotography is better than ever and offers fast films and colorful, fine-grained prints and slides. The primary strength of photography is its ability to give excellent definition over a wide field of view.

The greatest strength of video is that it puts astronomical imaging in the here and now. A video camera can grab an image from the focus of a telescope and deliver it intact to many viewers. You can record it on videotape for subsequent replay. Whether you observe in real time or study a tape weeks or months later, video allows you re-examine the captured moment again and again.

CCD still images are precise and linear over small fields of view. Because of their high sensitivity, CCD's and current image-processing software are suited for imaging planets and deep-sky objects. Once the image is captured, computer processing can extract all the information that's in the image.

The key to understanding imaging today is complementarity: CCDs, video, and film do different jobs. Video is best for movies, a CCD is best for precise images of small subjects, and film is best for sharp images of large regions of the sky. In today's amateur astronomy, there's room for them all. □

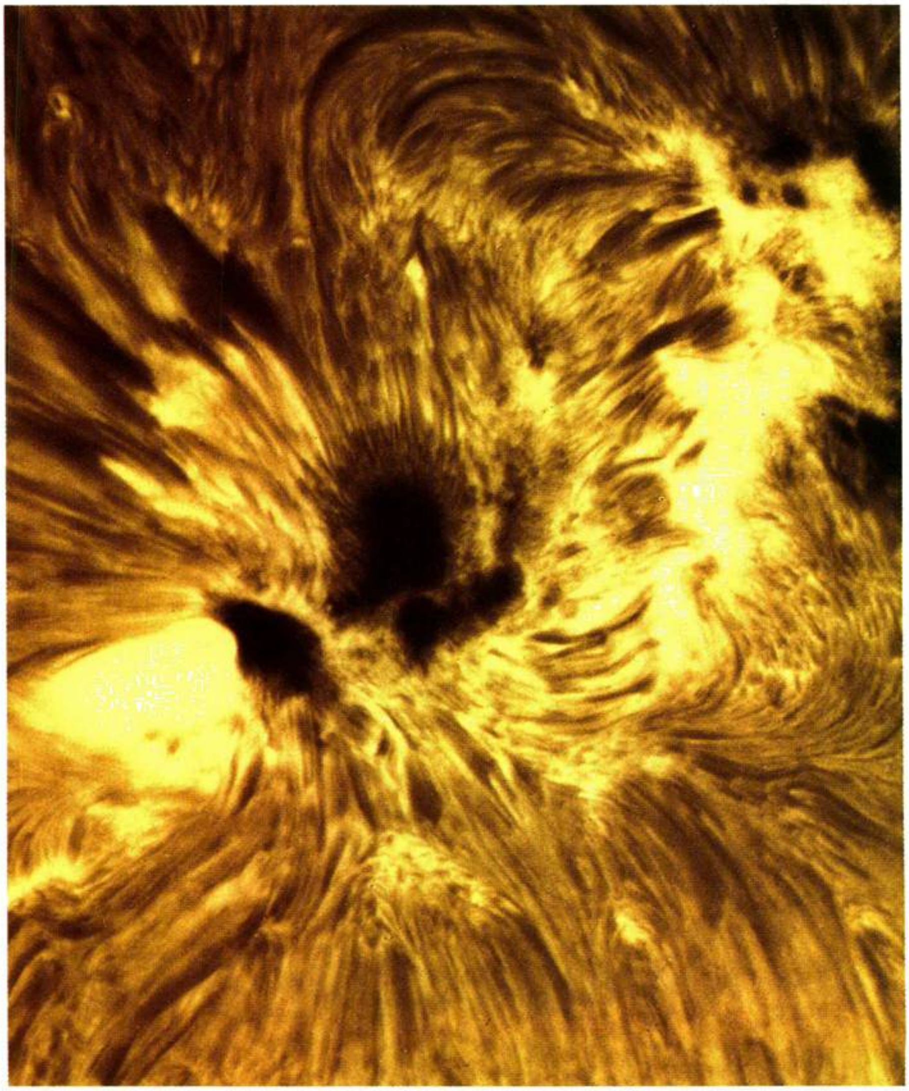
halftone off a0929-c0.tif
jup-4.tif

FLARES!

Observe explosive outbursts that change rapidly in brightness and can emit more energy in a second than some small stars.

by Richard E. Hill

When most people think of solar observing, they imagine views of sunspots or even wispy prominences seen at the Sun's limb. But they overlook the most energetic and dynamic phenomenon on the Sun's surface — flares. Most flares are small and visible only with telescopes equipped with expensive filters. But you can see large, white-light flares with a telescope fitted just with a standard solar filter. Part of the trick to observing these flares is learning where to look.

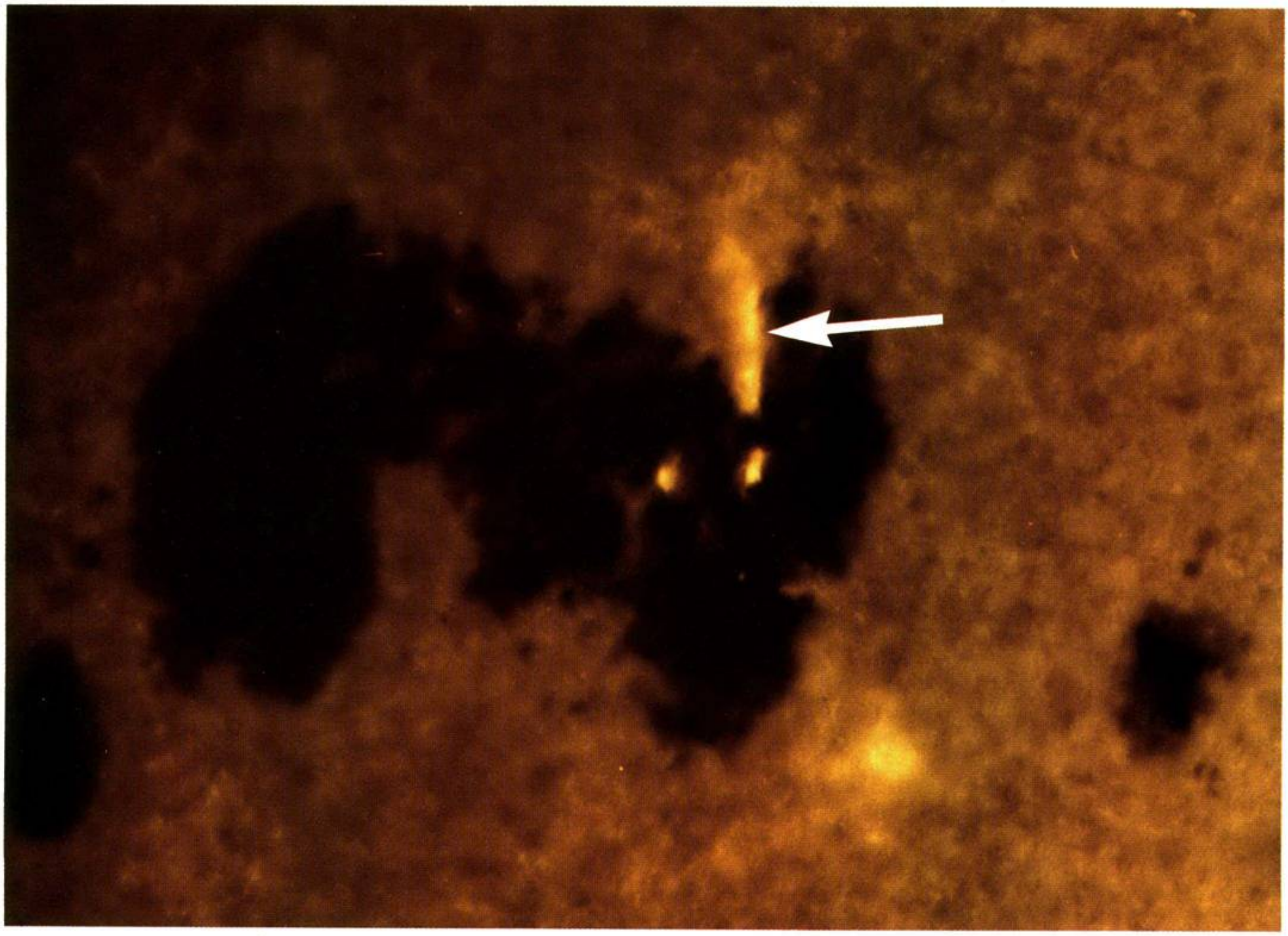


SOLAR FLARES ERUPT from the Sun's surface in or near spot groups, with most lasting less than 20 minutes. National Solar Observatory/Sacramento Peak photo.

Flares are short-lived, sudden brightenings of a region in the Sun's chromosphere — the layer of the Sun's atmosphere just above its apparent surface, or photosphere. They usually occur in or near sunspot groups. Flares quickly change in brightness and shape and sometimes appear as if they are erupting from the surface. Some flares race through the spot group. And you never know when or where the next outburst will occur, lending to the excitement when each flare erupts.

Most flares are visible against the bright photosphere only when viewed at one wavelength of light such as the red light of hydrogen-alpha. Compared to the flare's output at other wavelengths, the emission of this strong red hydrogen light increases the contrast between the flare and the photosphere. But flares covering a large area can emit prodigious amounts of energy. This huge outpouring of energy makes them visible even in white light. Large flares often eject protons and electrons at high speed into space, where they can crash into Earth, causing aurorae and disruptions in communications. Although most flares last ten to twenty minutes, large ones can last as long as four hours.

Flares are related to other forms of solar activity such as sunspots and prominences. In fact, flares often set off active prominences. As with other forms of solar activity, the number of flares varies over the activity cycle. Now is a good time for viewing flares because the Sun is



WHITE-LIGHT FLARES ARE RARE but can be seen with a properly filtered backyard telescope. National Solar Observatory/Sacramento Peak photo.

near the peak of its activity cycle, which means that flares will be numerous for another year or two. Of several thousand flares that occur annually at the peak of the activity cycle, a few percent will be large flares. Of the roughly 100 that occur each year near sunspot minimum, virtually none will be large or visible in white light. So there is no time like the present to start observing.

Where to Look

Observing large flares in white light takes patience since these flares are rare. Knowing where to look is the key to increasing your chances of seeing a flare, because certain sunspot groups are more likely to produce a large flare.

When looking for flares, it helps to understand what produces a flare in the first place. Flares are sudden releases of energy that occur in or near sunspot groups as the magnetic fields in the region change their configuration. The larger and more complex the sunspot group, the more likely the magnetic fields in the region will cross or become twisted, triggering a flare. Most flares occur in spot groups where a flare has already occurred. In fact, some groups produce ten or more flares, although most of these will not be white-light flares. Therefore, predicting future flare sites is roughly equivalent to determining which sunspot groups have complex shapes.

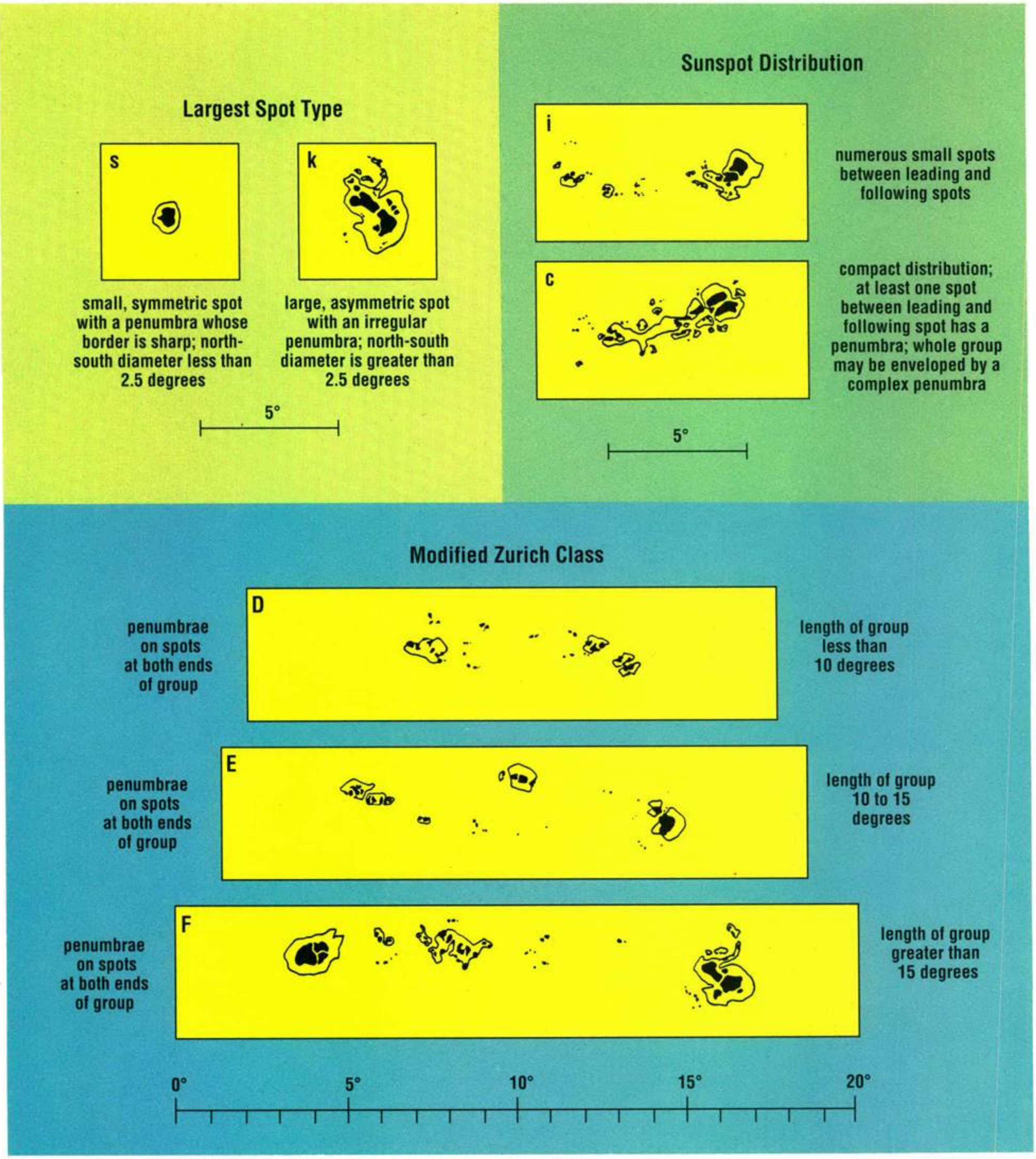
Solar astronomers use special systems to classify sunspots and sunspot groups. The classification system developed by Patrick McIntosh is most useful for flare observations because it indicates which sunspot groups are most likely to produce a flare. McIntosh, a solar astronomer at the Space Environment Lab (National Oceanic and Atmospheric Administration), uses a three-letter system that describes the size of the group, the shape of the largest spot in the group, and the distribution of spots within the group (see Flare Hunter's Field Guide on page 76).

The first letter, a capital letter ranging from A to H (excluding G), is called the Modified Zurich class. Small groups are labeled A, B, or C and are not of interest to white-light flare observers. D class groups extend less than 10 degrees across the Sun's surface, E groups from 10 to 15 degrees, and F groups over 15 degrees. H groups are usually the remains of large groups that are decaying and, like the small A to C classes, usually do not produce large flares.

The second letter describes the largest spot in the group. Of most interest to flare observers are the s and k classes. Class s groups have a small (less than 2.5 degrees in the north-south direction) and symmetric spot as the largest spot in the group. If the largest spot is large and asymmetric, the group is class k.

The third part of the classification scheme is also a small letter and denotes the spot distribution in the group. Intermediate distributions, class i, have many tiny spots that lie between the leading (westernmost) and following (easternmost) spots of the group. Compact distributions, class c, may have the same spatial extent as class i groups,

FLARE HUNTER'S FIELD GUIDE


Largest Spot Type
s
k
small, symmetric spot with a penumbra whose border is sharp; north-south diameter less than 2.5 degrees
large, asymmetric spot with an irregular penumbra; north-south diameter is greater than 2.5 degrees
5°
Sunspot Distribution
i
numerous small spots between leading and following spots
c
compact distribution; at least one spot between leading and following spot has a penumbra; whole group may be enveloped by a complex penumbra
5°
Modified Zurich Class
D
penumbrae on spots at both ends of group
length of group less than 10 degrees
E
penumbrae on spots at both ends of group
length of group 10 to 15 degrees
F
penumbrae on spots at both ends of group
length of group greater than 15 degrees
0°
5°
10°
15°
20°

drawings by Richard E. Hill

but the spots in between the leading and following spots have penumbrae, lighter regions surrounding the dark umbra of the spot.

Based upon flare observations made over the last twenty years, groups of Modified Zurich class F have a 60-percent chance of producing a flare in the next 24 hours. Groups that have a largest spot class of k have a 40- to 50-percent chance of flaring, while the chance of a flare increases to 70 percent for groups with a spot distribution category of c. But the highest probability of seeing a flare occurs for groups of type Fsi, Fki, and Fkc. These groups almost always produce a flare within the next 24 hours!

While you can learn McIntosh's classification system in detail, you really do not need to understand the nuances of the system. Rather, a simpler approach is to look at spot groups that have large spots at each end and numerous small spots in between, and whose largest spot has a complex shape. Although this spot group will have a good chance of producing a flare in the next 24 hours, your chance of observing it is small unless you spend some time monitoring the spot.

Set your telescope up (be sure it is properly filtered — see page 78) and look at the spot groups. If a promising group is visible, leave the scope set up for several hours and check the group several times each hour. Be sure that if you leave your scope unattended, unsuspecting passersby — especially children — won't be able to directly view the Sun and damage their eyesight. Remember, ten to twenty minutes is the lifetime of a typical flare so you don't need to check more often than that. If you check less often, you run the risk of missing a flare. The longer you observe, the better your chance of catching a flare in action.

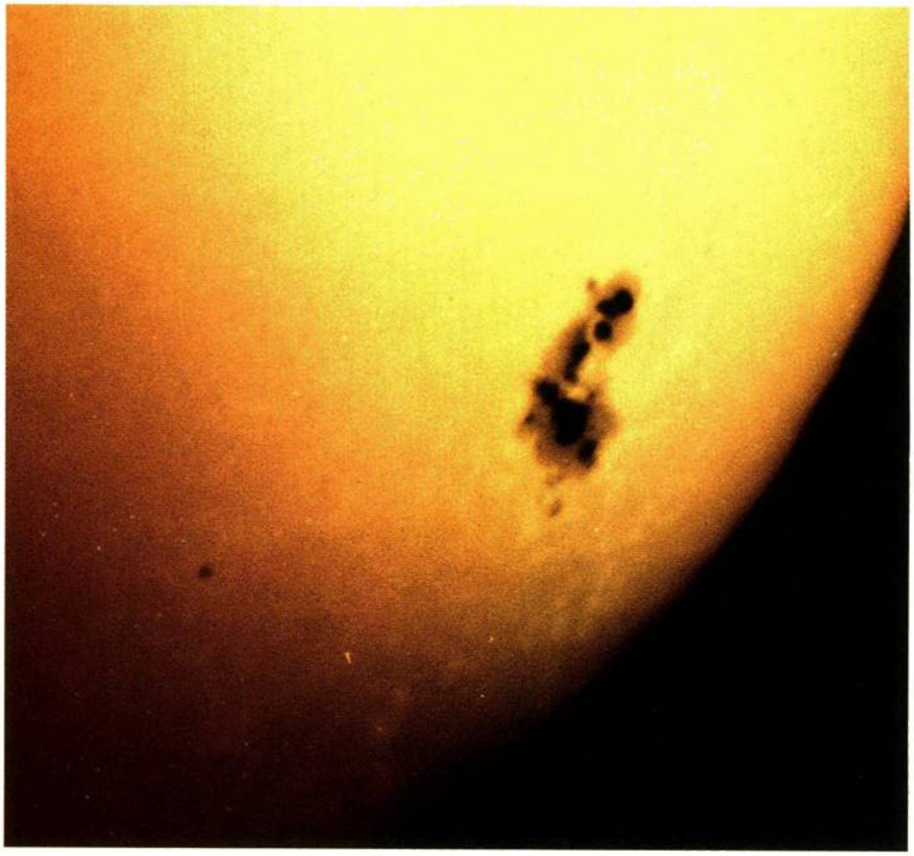
What to Look for

Many white-light flares will not appear very large because most of the activity is occurring up in the chromosphere. H-alpha filter observations show a large flare, but in white-light you may see only bright points about one or two arcseconds across, the size of a photospheric granule. If you are lucky, these points will grow in brightness, merge together and (if you are *very* lucky) become a bright ribbon.

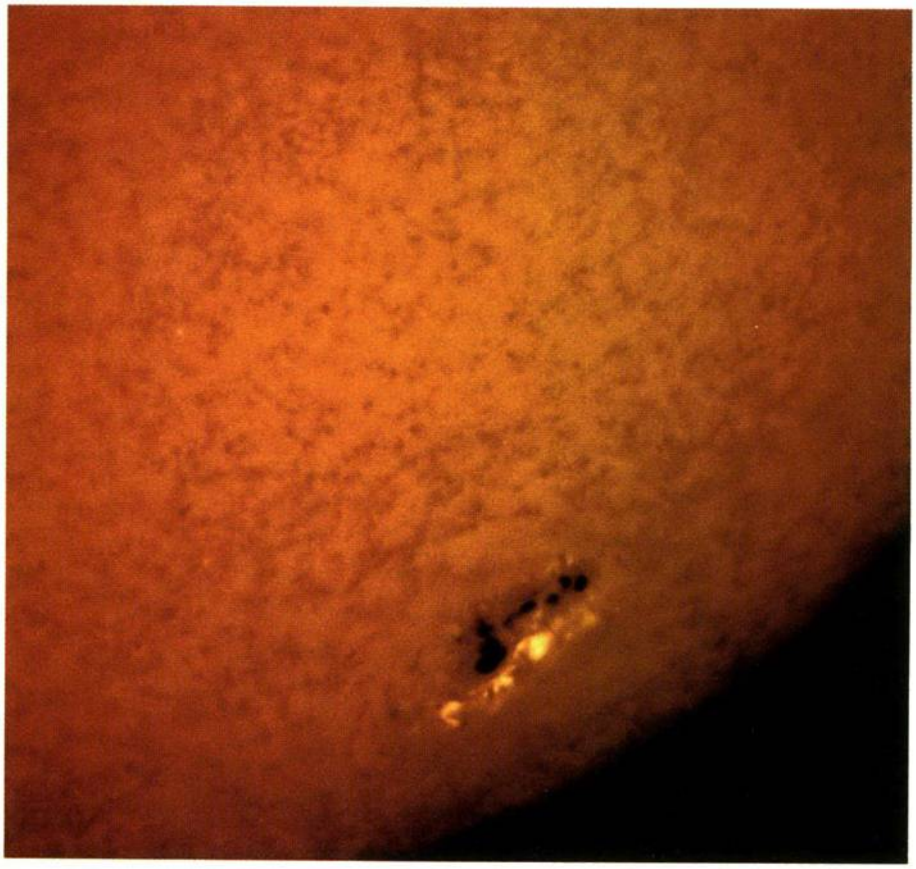
Some sunspot groups show changes that are precursors to flares. Groups that have their spots rapidly rearranged in a line are a good site for flares. Groups that have rapidly moving spots, large spots that are breaking apart, and spots that have complex penumbral regions may produce flares. (If you have an H-alpha filter, you may see filaments near a flare site undergo rapid change in shape or brightness.)

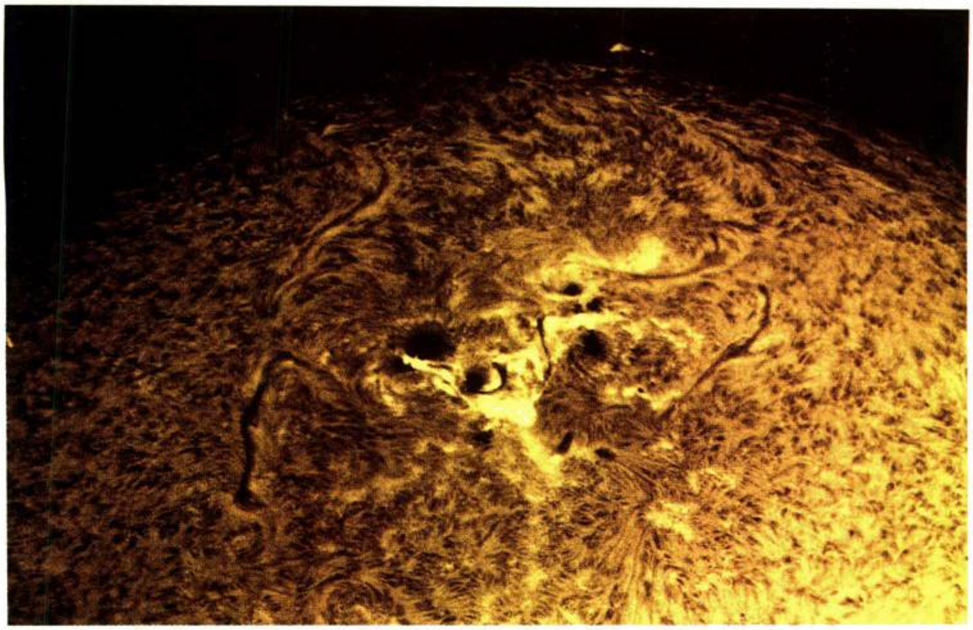
Stopping down your telescope also can increase your chances of seeing a flare in white light. Fit your telescope with an aperture mask to change the f/ratio to f/20 or longer. This will increase the contrast of the flare against the photosphere. Daytime seeing conditions are rarely better than a few arcseconds so there will be little, if any, loss in resolution.

You can also increase your chances of seeing a flare by using a Mylar-type prefilter. The bluish appearance of the Sun produced by this filter (and detested by some amateurs as artificial compared with the Sun's yellowish-white appearance) indicates that the filter transmits more blue light than red light. This is a benefit for observing flares since there are many more spectral lines in the blue part of the Sun's spectrum than in the red. These blue spectral lines, which are produced in the photosphere, normally appear dark. During a flare, these lines go into emission, making the flare appear bright against the photosphere and, thus, easier to see. The broadband



SUNSPOTS LOOK DIFFERENT in the red light of hydrogen (bottom) than they do in white light (top). Both photos by Don Trombino.





H-ALPHA FILTERS ENABLE you to see small flares such as this one captured by Jean Dragesco.

nature of the filter, though, makes the transmitted light "white."

Observing in H-alpha

To increase the number of flares you can see, you need an H-alpha filter. H-alpha filters wider than one angstrom won't do the job because they pass too much light from the photosphere, reducing the contrast of the flare. Unfortunately, the narrowband filters required are expensive.

The simplest filter consists of a telescope prefilter and a narrowband filter housed in a tilting mechanism to allow you to tune the filter to the proper wavelength. This is important because temperature changes affect the filter. More expensive filters use a temperature-controlled oven to maintain the wavelength of the filter. Also, the less expensive filters have a wider passband than the more expensive ones. The more expensive filters, therefore, produce greater contrast.

The task of observing is the same as for white-light flares. It is somewhat easier because smaller flares now become visible, increasing your chances of seeing one. At first, it is hard to recognize the sunspot groups in the light of H-alpha. More structure is visible in the chromosphere around sunspots than in the photosphere seen in white light. So you may want to use a Mylar-type prefilter on your telescope first in order to sketch the positions and appearances of some of the spot groups. This drawing will help you find the spot groups after you install the H-alpha filter.

An ideal setup would be to have two telescopes, one with an H-alpha filter and the second with a Mylar-type prefilter. If you see a flare in the H-alpha scope, you could check to see if it was also visible in white light.

Whether you have a scope with just a Mylar-type prefilter or one equipped with an H-alpha filter, try searching the Sun for flares. If you see one, the dynamic outburst of the event will amply convince you to observe the Sun more often. ☐

Richard E. Hill is the recorder for ALPO's Solar Section and resident observer at the Warner and Swasey Observatory Kitt Peak station.

OBSERVE THE SUN SAFELY!

The first rule of solar observing is NEVER OBSERVE THE SUN DIRECTLY! Damage to the eye occurs almost instantly and is permanent. Because your retina cannot feel pain, there is no warning that it is being damaged.

Projection methods are by far the safest way to observe since the Sun's light is not viewed directly. But the low contrast usually provided by this method makes it difficult to observe phenomena such as flares. They require direct viewing through a properly filtered telescope. If you are ever in doubt whether a telescope is properly filtered, play it safe and don't look.

The only safe way to observe the Sun directly through a telescope is with a prefilter. The filter should be securely fastened over the front end of the telescope where it prevents most of the Sun's light from entering the telescope. The filter reduces the Sun's brightness by about one million times and blocks the ultraviolet and infrared radiation that can damage your eyes. Although there are some different versions of this filter, one commonly used by amateurs is an aluminized Mylar-type filter.

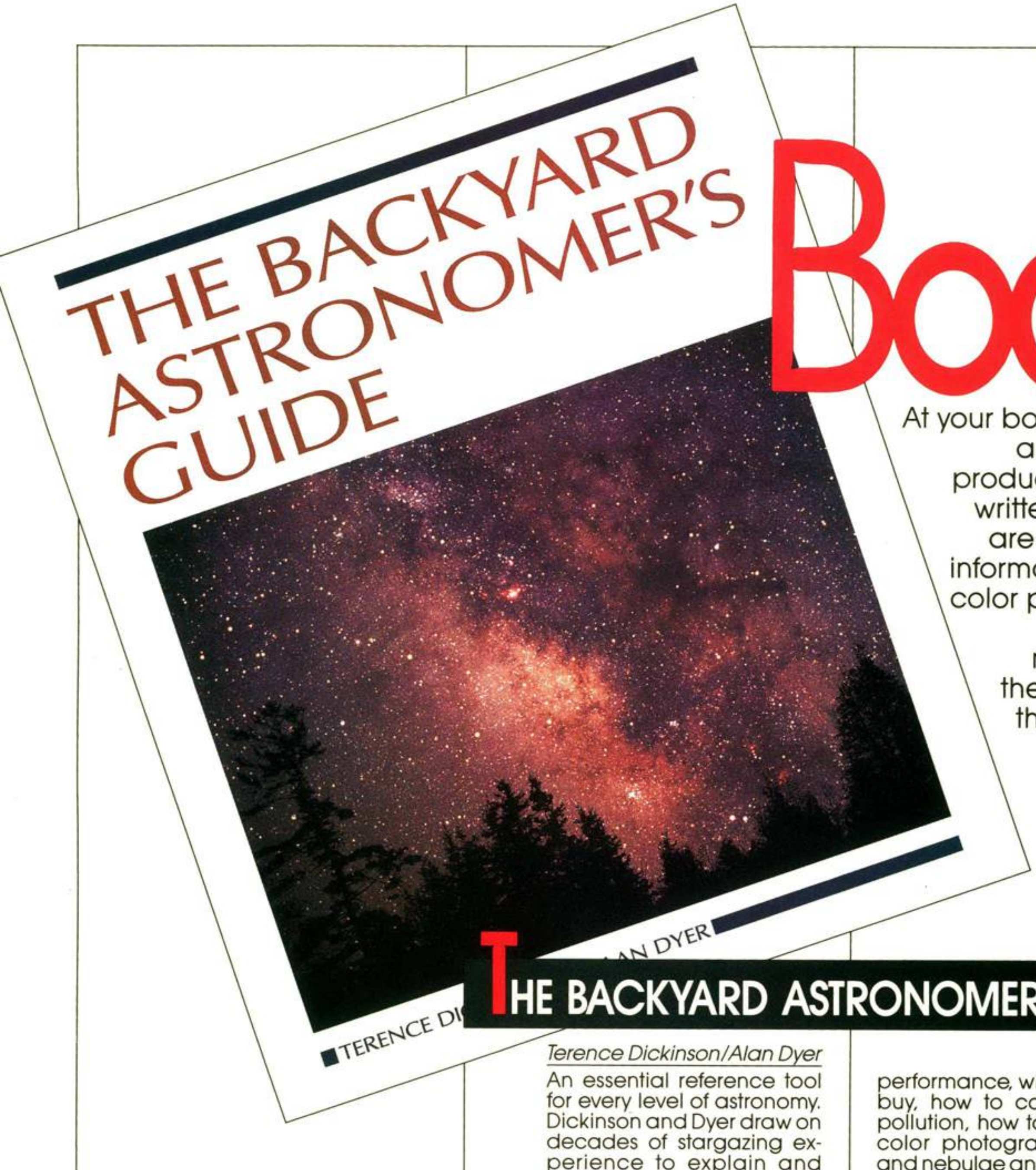
Eyepiece filters used alone are dangerous! This type of filter is often provided with inexpensive telescopes and should be discarded for your own safety. Heat in the telescope can build up and crack the filter without warning.

Another potential danger is the finderscope. Cap the finder so that light cannot pass through it and inadvertently shine in someone's eyes. You can still aim the telescope quite easily without the finder by moving the telescope around until the telescope tube produces the smallest shadow. With a low-power eyepiece in the focuser, you should be able to center the Sun quickly with this shadow method.

For amateurs looking for a different challenge in observing and photographing the Sun, H-alpha filters permit viewing of the chromosphere. This layer of the Sun lies above the so-called surface, or photosphere, and is the region where prominences form. Also, small flares are visible in H-alpha. These filters are quite expensive, however, with wide-band filters starting around $750. Narrow-band, temperature-stabilized filters cost as much as $3,000, but they offer the best views of the Sun's chromosphere. Most of these filters are made by Del N. Woods of Daystar Filter Corporation, but are available from many distributors.

H-alpha filters require a prefilter to cut down on the light entering the telescope. These reddish filters pass most of the red light, but block blue light. The H-alpha filter itself transmits only a small portion of the red light that passes through the telescope. The combination of red prefilter and H-alpha filter reduces the amount of light sufficiently that it is safe to look through the filter directly.

For more information about observing the Sun and flares, contact the solar section of the Association of Lunar and Planetary Observers at ALPO Solar Section, 4632 East 14th Street, Tucson, AZ 85711-4216.


THE BACKYARD ASTRONOMER'S GUIDE
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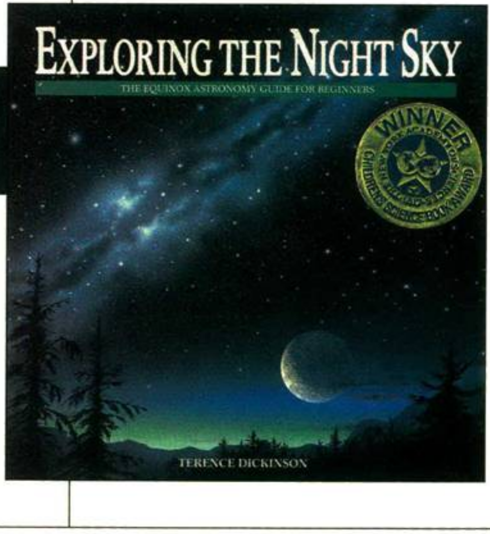
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FIREFLY BOOKS

A Personal and Permanent Journey through the Universe

Time spent beneath the stars with a journal will richly reward astronomical memories.

by Gregory L. Zentz

The sky looked great all day. You load your telescope and observing equipment into your car, bundle up, and take off for a wonderful night of observing. You arrive, set up your telescope and lawn chair, and stare up at the star-rich, velvety black sky. Will this night be any different than previous nights? Will you end up merely taking 10-second glances at all of the objects you looked at last time out?

If you're looking for some added zip from your hobby, try keeping a log of your observations. I find a 3-ring notebook especially flexible, and its hard cover provides support while I'm working. Logging observations not only is an exciting project in itself, but records what you've seen for later years. There's nothing more satisfying to me than pulling out an observing journal from a few years ago and re-attending a past observing session. Moreover, keeping a log teaches you to look carefully at objects, which makes you a better observer. And who knows — you may discover and record something of great importance, a supernova, a new comet, or an unexpectedly intense meteor shower. After all, who would remember Galileo if he hadn't recorded the changing positions of tiny moons he discovered orbiting Jupiter?

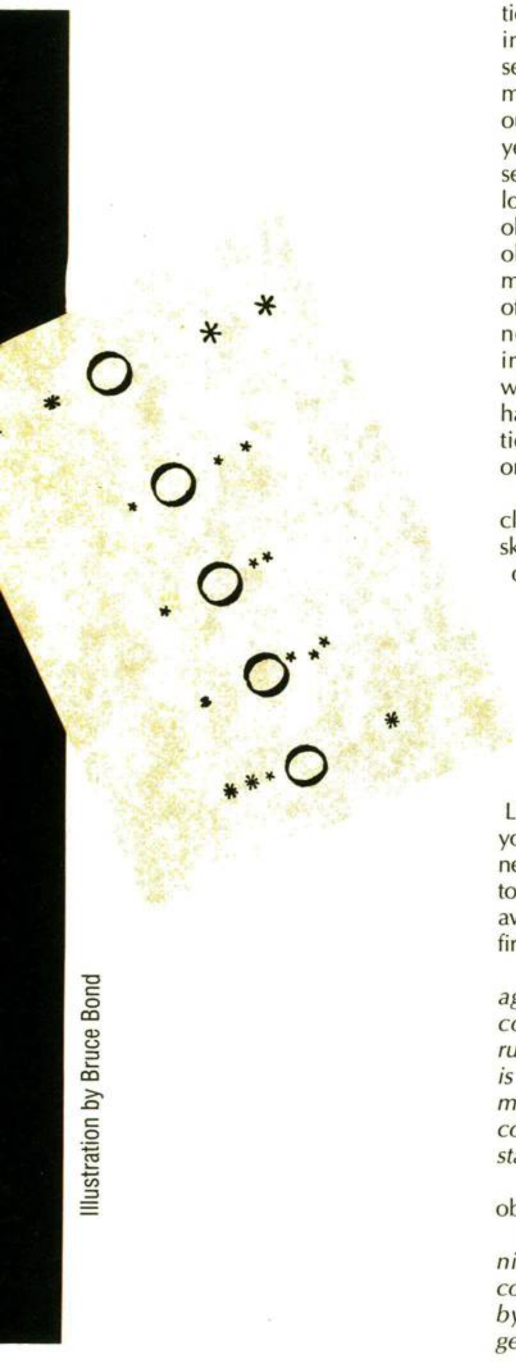


Illustration by Bruce Bond

To begin your journal, start on a clear, dark night. Select a part of the sky you're familiar with, and choose one or two objects to observe. Start with a constellation you'll see again during your next observing session. Write the name of the constellation at the top of a blank sheet in your journal. Jot down a few interesting facts you remember or observe about that constellation. Leave space to add information as you go along. Begin in a simple manner — don't knock yourself out trying to find out everything you can right away. Here's an example of how the first entry on a page might look:

ORION. Hunter holding shield against Taurus the Bull. Brightest constellation in the sky. Orion is running away from Scorpius, which is directly opposite it in the sky. A multiple star system in Orion, Rigel, contains one of the most luminous stars in the Galaxy.

Next, mention a few interesting objects in the constellation:

Mintaka, also called Delta Orionis, is a fine triple star system. It contains an eclipsing binary orbited by a distant blue companion. Together they form a nice double star composed of magnitude 2 and 3 suns. Mintaka is one of the bluest and hottest stars visible.

That done, leave Orion alone, move to another blank sheet of paper, and examine the next constellation. Why not do Taurus? Your entry might look like this:

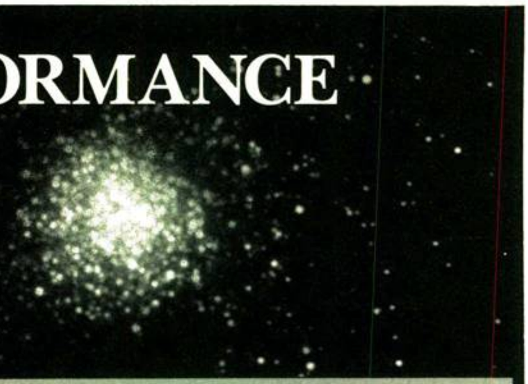
NGC 3489. A magnitude 11.5 elliptical galaxy with the Herschel number H101^2*. Star-hop to this object by moving 30' north and then 2.3° east of the galaxy NGC 3412. NGC 3489 measures 2.0' by 0.9' in extent and appears bright and circular in my 10-inch scope. A wide-field eyepiece shows an asterism resembling a cross with three field stars; the galaxy lies at the end of the right-hand crossbar in this asterism.*

Use each constellation sheet as a guide to your observing for a particular evening. Don't try to fill up a given constellation all at once. When you get your new issue of ASTRONOMY and come across the description of an object, add the information to your journal. You should also consult various books for data to add to the compilation. The following are especially useful: *Burnham's Celestial Handbook* by Robert Burnham, Jr., (Dover Publications, New York, 1978); *Messier's Nebulae and Star Clusters* by Kenneth Glyn Jones (Cambridge University Press, 1991); *Observing the Constellations* by John Sanford (Simon and Schuster, New York, 1989); and *The Universe from Your Backyard* by David J. Eicher (Cambridge University Press and AstroMedia Corp., New York, 1988).

If you've got a computer or word processor then look out — it'll be really easy! Each time you add new objects to a constellation, make a printout of the page, punch holes in the paper, and replace the dog-eared version in your journal.

Once you've gone through a few observing sessions with your journal, using it will seem automatic. It will add a new dimension to your observing and give you a personal record of your journey of exploration through the universe. After you keep a journal for several observing seasons, you'll be astonished at the amount of material you'll collect — so much interesting stuff that even Galileo himself would be impressed. □

Gregory L. Zentz is a freelance writer and amateur astronomer living in Jacksonville, Florida.



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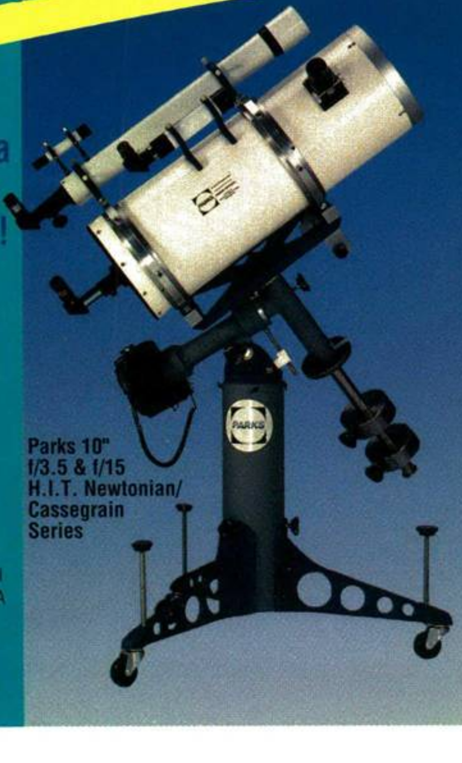

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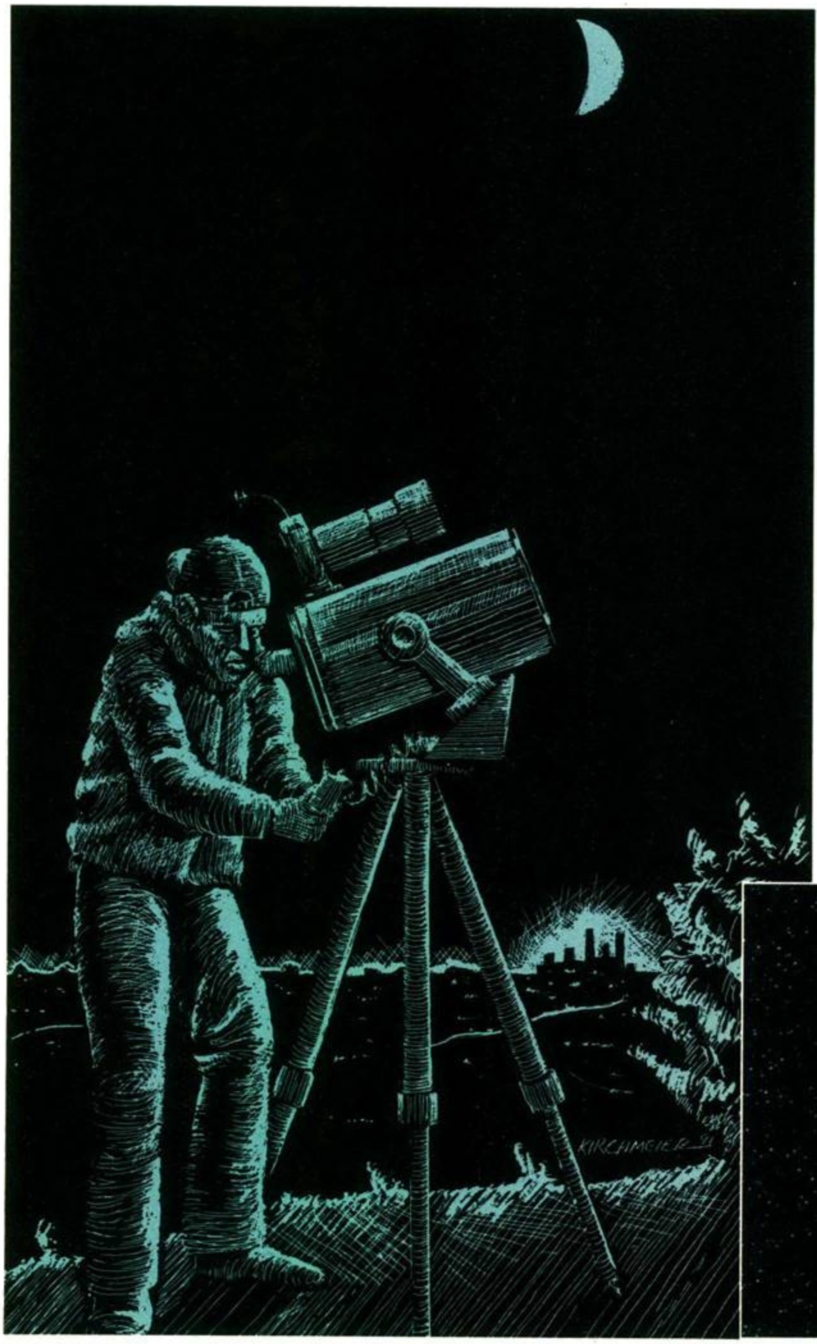
MOONLIGHTING

They said it couldn't be done — you can't take deep-sky photos when the Moon is up. Not so! All it takes are the right film and filters.

By Robert Reeves

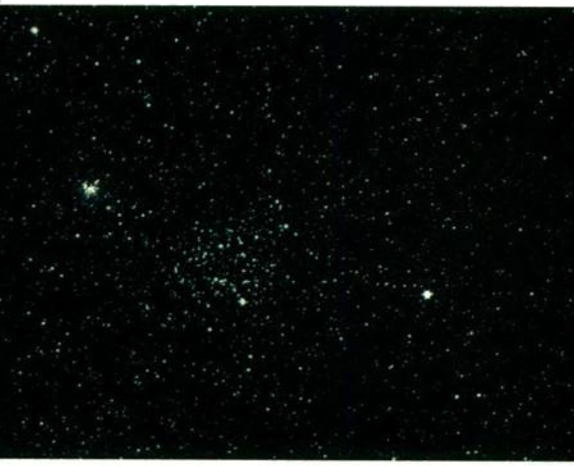


As a deep-sky astrophotographer, I have always regarded moonrise as something akin to sunup — that is, end of game, dance over, time to pack up and go home. Like most other sky shooters I figured that moonlight is so bright that it would hopelessly fog any attempt to capture deep-sky objects in long-exposure photos.

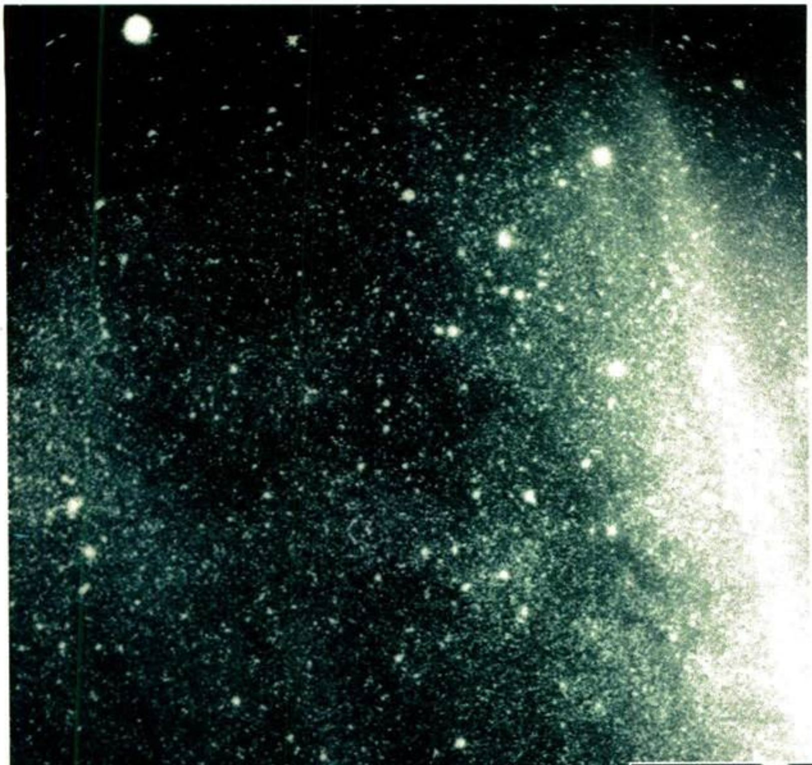
Recently, my astrophotography friends and I have discovered this isn't necessarily so. We have taken successful deep-sky exposures with lunar phases all the way up to a seven-day-old Moon near the area we were shooting. The secret of our success in combating moonlight is to use one of several commonly available filters.

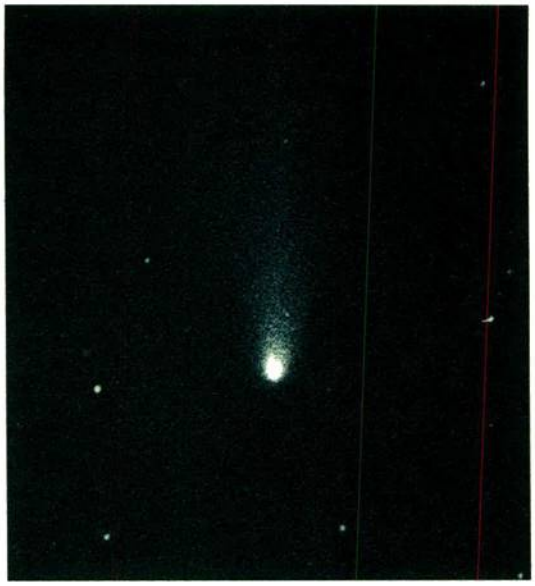
Red Lights Only

For black-and-white astrophotography, Lumicon's deep red H-alpha-

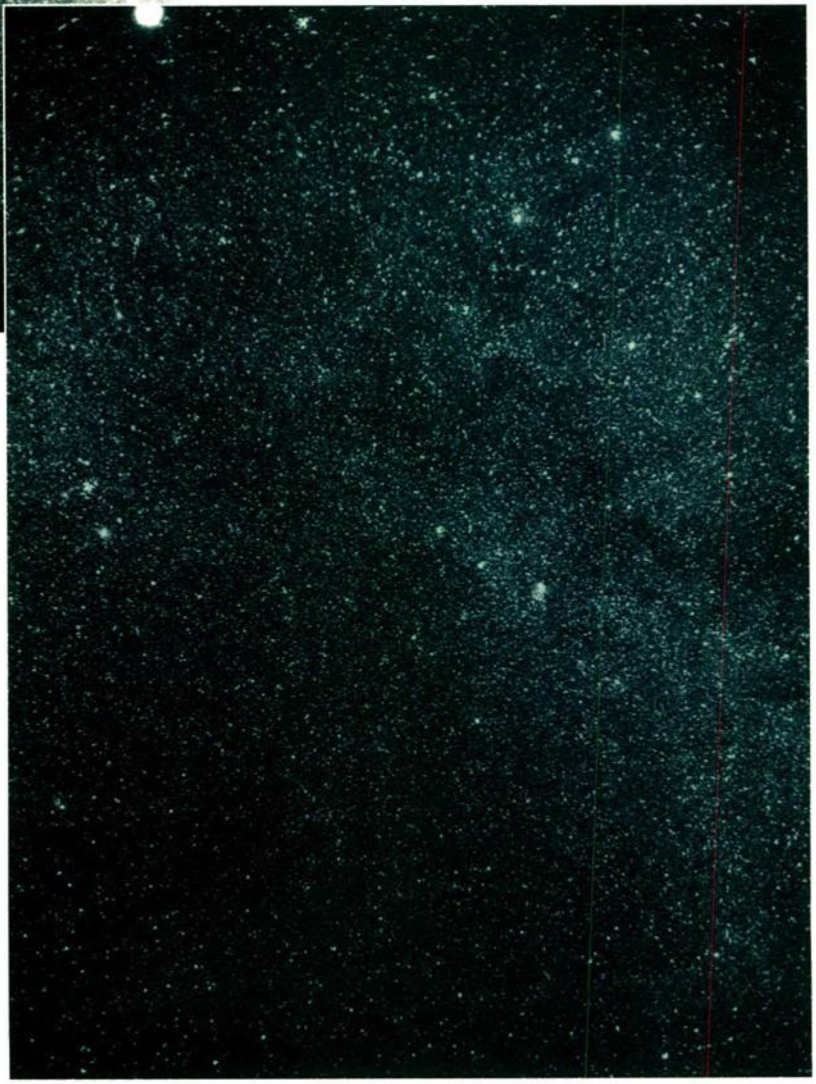


WITH A QUARTER MOON NEARBY, the author captured the star clusters M35 and NGC 2158. Hypered Tech Pan film combined with a #92 red filter was the key for this 15-minute exposure with an 8-inch f/1.5 Schmidt camera.

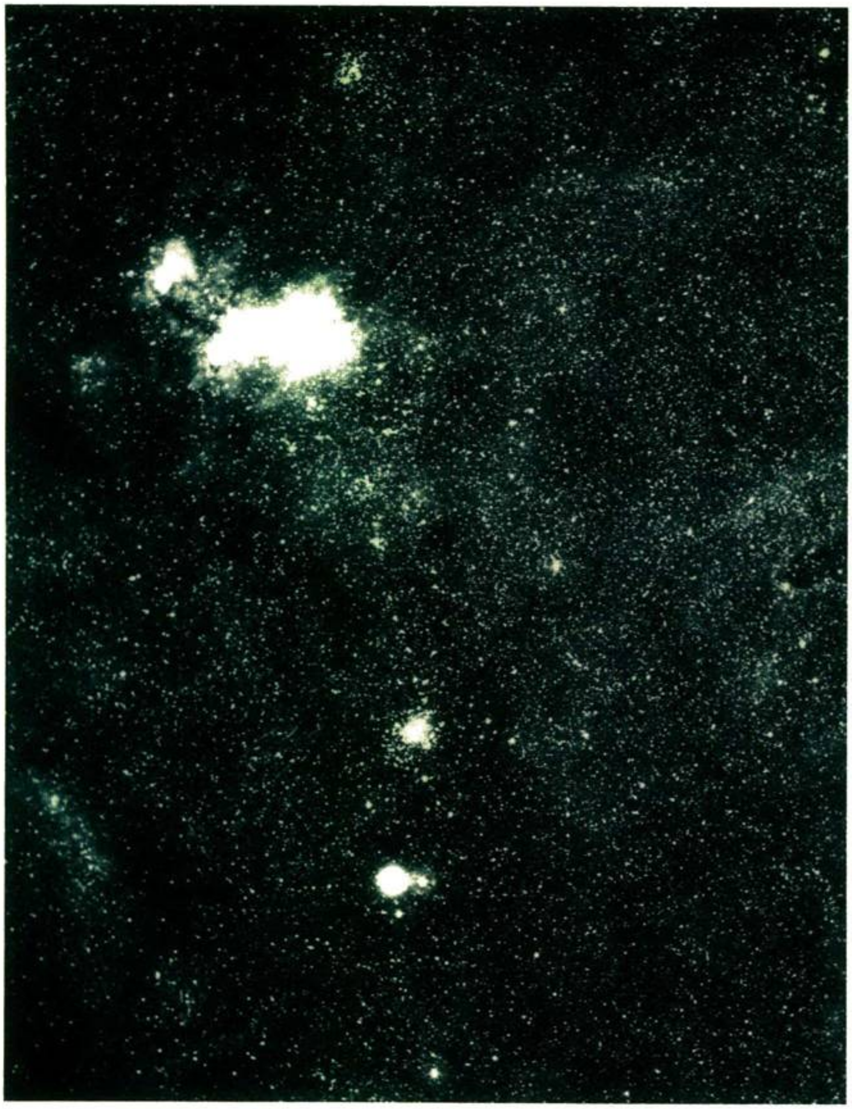




USING A POLARIZER, the author recorded Comet Halley with a bright Moon 90° away from the comet. This is a 4-minute exposure on hypered Tech Pan film.



BEFORE AND AFTER SHOTS TELL THE TALE. Above is a 12-minute exposure of the Milky Way below Canis Major taken in moonlight. The photo is badly fogged. At right is the same area photographed through a Lumicon H-alpha-pass filter (a very deep red filter) for 30 minutes. The sky background looks as black as it would if the photo were taken with no Moon in the sky. Both photos by Richard Mischke.



PIERCING THE MOONLIGHT with a #92 filter allowed the author to record nebulosity and clusters in southern Scorpius. Despite the presence of the Quarter Moon, a 33-minute exposure with an ultrafast 8-inch f/1.5 Schmidt camera still gave a dark background and good contrast.

pass filter will cut out urban light pollution. But it also effectively blocks the light of the Moon because moonlight scattered around the sky is blue, just like scattered sunlight around the daytime sky. By using a red filter you can get dark-sky photos in a bright moonlit sky.

Another suitable red filter is a Wratten #92. These are sold as gelatin filters at well-stocked camera stores and are cheaper than the H-alpha models. For piggyback photography, you can get special clips to hold gelatin filters in front of a camera lens. For prime focus shots, gel filters can also be inserted at the back of an off-axis guider. I use a #92 gelatin filter with an 8-inch Schmidt camera because it isn't possible to insert a glass filter into the Schmidt's film holder.

For piggyback photography, another filter effective against moonlight in some limited cases is a polarizing filter. Most daytime photographers are familiar with the effect of polarizers — they darken the sky 90° away from the Sun. But a polarizer can work at night as well, darkening the sky 90° away from the Moon.

A polarizer is a dark filter, however, and your lens will lose the equivalent of two f/stops with the filter in place. Exposures will have to be four times longer than what you might normally use. In addition, since it is only effective when shooting sky regions 90° away from the Moon, a polarizer might seem of limited use. But on some occasions, it may mean getting what would otherwise have been an impossible photograph. For example, a few years ago I was able to capture good images of Comet Halley, photos that without the filter would have been ruined by the glare of the Moon.

Tips in the Moonlight

To work with deep red filters such as a #92 or H-alpha, you need a film that is sensitive to red light. The best choice is Kodak Technical Pan 2415. But it must be gas hypered to increase its sensitivity during long exposures. Tech Pan can be purchased pre-hypered from several suppliers or you can hyper film at home yourself using one of Lumicon's kits.

Another consideration is that a black-and-white negative need not be perfectly transparent. A clear negative means a black sky, but in practice some greying of the sky background is still acceptable. As long as the background density of the negative does not overpower the faintest objects being recorded, you can still end up with a good print. This is especially true if the target is a star cluster, such as in the photo of M35 and NGC 2158 on page 83. As long as the stars are burned in, the dense sky background will not overpower them. The denser negative will simply require a longer printing time.

This latitude does not apply to color slide film. A bright sky will wash out transparencies. In addition, there's no point using color film with filters like an H-alpha or #92 that cut out all the colors except red. Fighting moonlight is best left to black-and-white film.

Another requisite is good sky conditions. High humidity, dust, or haze that would be illuminated by moonlight and brighten the sky will be detrimental to deep-sky photos, even with filters and Tech Pan film. Moon or no Moon, a clear, transparent sky is still essential.

Being able to take deep-sky photos with up to a Quarter Moon in the sky is like getting an extra dark-of-the-Moon week each month. Between clouds and commitments during each New Moon, it seems you never get enough clear nights to get the photos you want. This moonlighting technique opens up the calendar, virtually doubling the time available to chase deep-sky targets. ☐

Robert Reeves is an avid astrophotographer living in San Antonio, Texas, and is a frequent contributor to ASTRONOMY.

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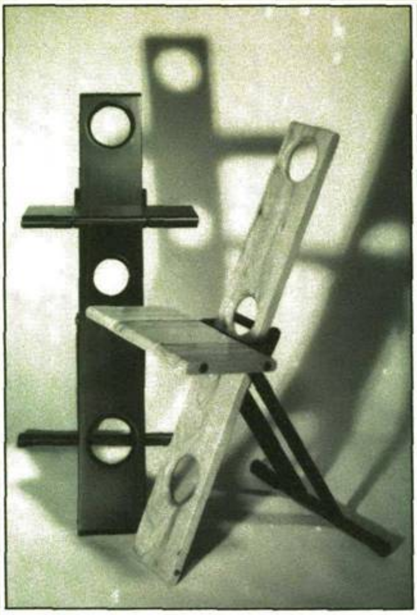

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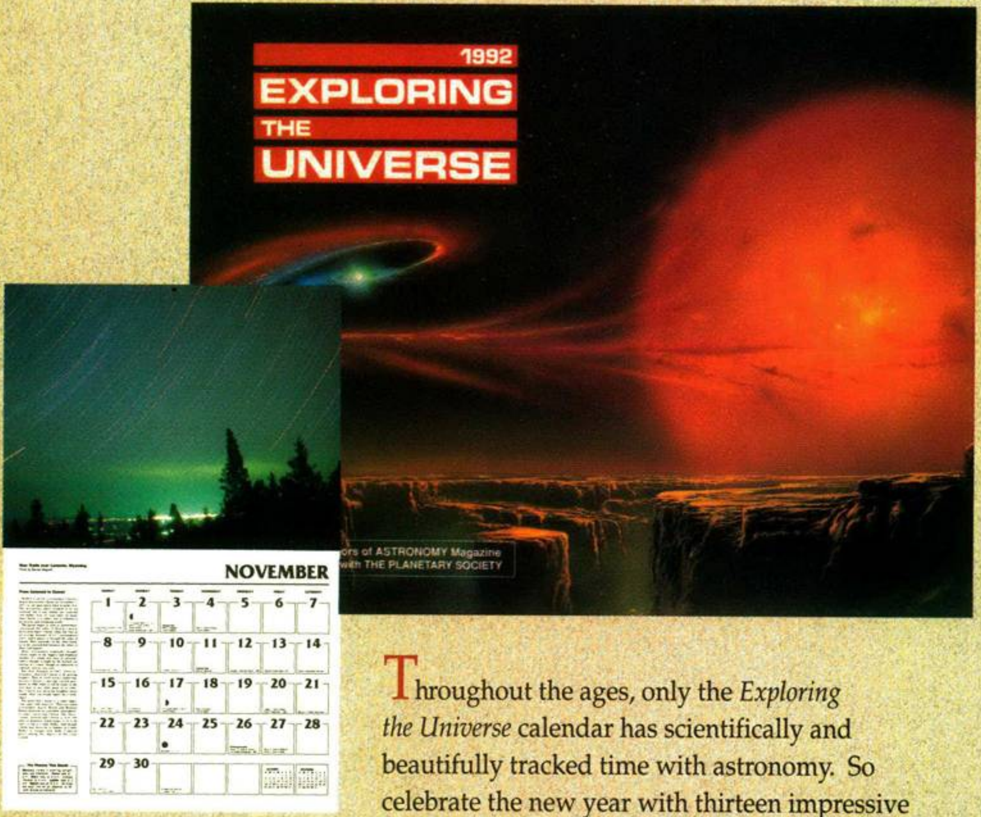

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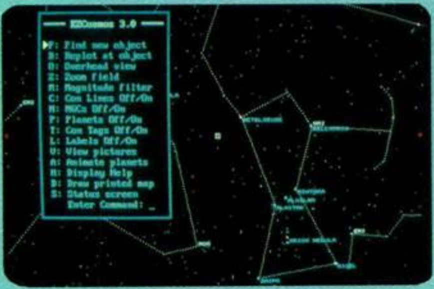
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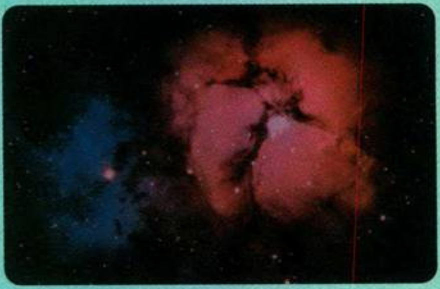

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A PEAK EXPERIENCE AT MAUNA KEA

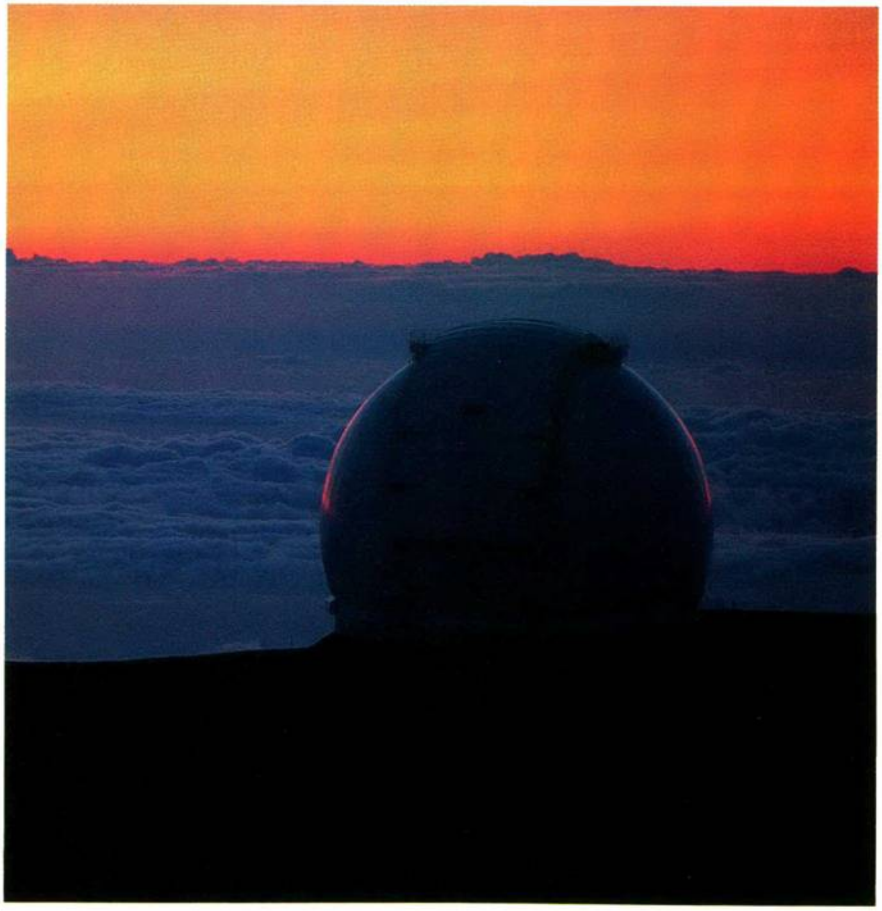
As a hedge against the unlikely cloud-out of last summer's solar eclipse in Hawaii, Californian Ivan Dryer signed up his group of three for a sunset tour of the observatories atop Mauna Kea. The Kona-based company, Paradise Safaris, offered afternoon-through-night excursions up the mountain, so Dryer and his friends decided to take part in what became a memorable evening.

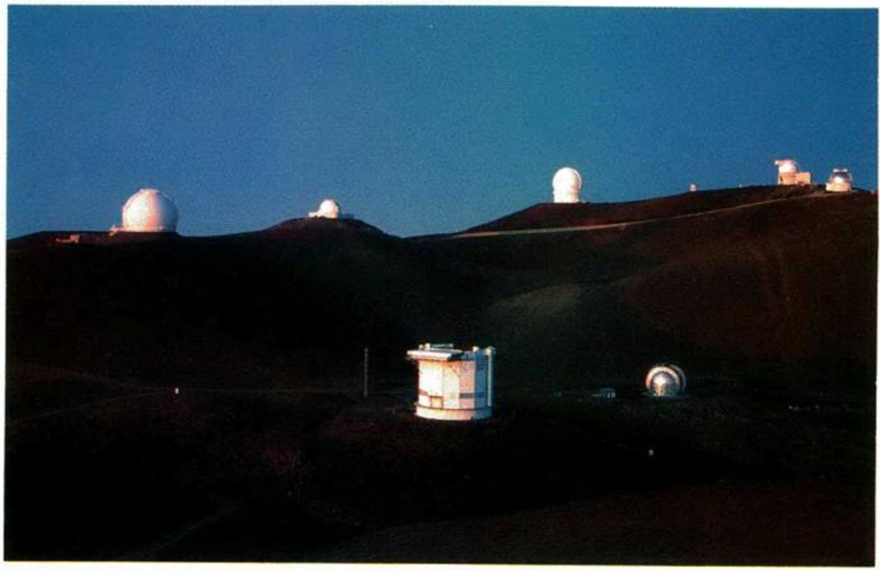
"Never having been up the mountain, we had a few trepidations about the 14,000-foot altitude," says Dryer. It was July 12, the day after the eclipse, when Dryer and friends set out to pass through the clouds and come out on top of the peak. "The thing that first strikes you is that from below, Mauna Kea seems to be always in clouds," says Dryer. "When you reach the summit, you discover you're above the clouds."

From the summit the visitors felt like they were "on top of the world." South of the mountain lies the long, black hump of Mauna Loa, looking "like the back of a monstrous, beached whale." Northwest of Mauna Kea lies the volcano Haleakala on the island of Maui. "Just about this time we recovered from being stunned at the view and noticed it was quite cold on the summit," says Dryer.

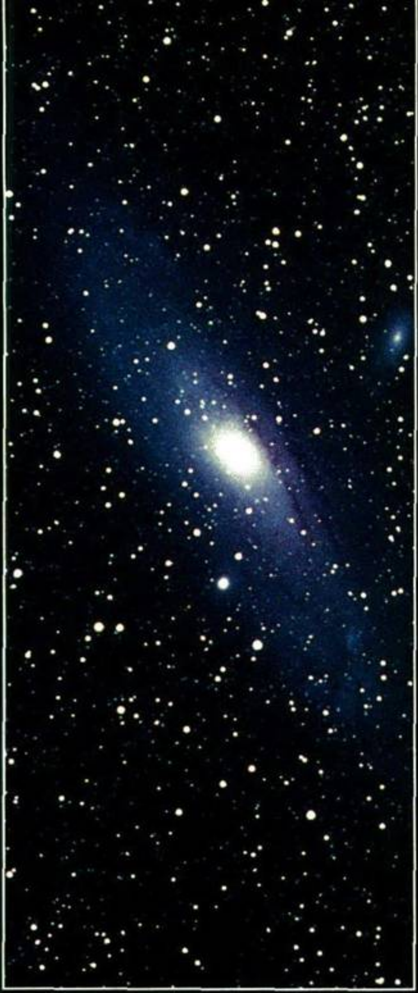
The most exciting time for Dryer and friends came as the Sun inched down toward the horizon. "Color began to flood the sunset zone," reports Dryer. "The slim crescent Moon and Venus lined up with the dome of the Keck telescope. A violet haze — doubtless caused by dust from Mount Pinatubo — permeated the horizon like a great, glowing curtain. This was really a *sunset*."

As the sky darkened, the Milky Way came out for the visitors. "The Milky Way was brighter and more contrasty than I've ever seen it," says Dryer. Star clouds and dark nebulae stood out in sharp relief with a pair of binoculars. Omega Centauri was an incredible array of countless points in an 8-inch scope positioned on the summit. The Lagoon Nebula appeared as a "revelation" in Dryer's 5-inch SCT. For a group of eclipse chasers who were partly clouded out, a trip to the summit of Mauna Kea was truly 1991's peak experience. — *David J. Eicher*





THE KECK TELESCOPE DOME looms large against a Mauna Kea sunset during Ivan Dryer's post-eclipse trip to the observatory (top). Daylight shows the multitude of telescopes on the mountain (above). Photos by Ivan Dryer.



ASTRONOMY ROLLIN' DOWN THE TRACKS

Robert Bunge of Laurel, Maryland, is an avid reader of both ASTRONOMY and its sister publication Trains. "I've waited more than six years to take a photograph that could be published in both magazines," exults Bunge. "You must print it!" Bunge's photo (opposite page) shows Jupiter, Venus, and Regulus hovering over an ex-Norfolk and Western Class A steam engine (locomotive #1218) as it pulled out of Manassas Junction, Virginia, on September 29, 1991, bound for Lynchburg. Not only does the image win this month's $100 "Best Astrophoto" award, but office scuttlebutt suggests the photo may show up in Trains.

While planets and trains occupied Bunge last autumn, other readers were busy shooting deep-sky objects. Gérard Therin photographed the Veil Nebula (below) with a 4-inch f/5 lens and hypersensitized Tech Pan film. The exposure lasted 105 minutes. A deep exposure of the Andromeda Galaxy (left) was produced by Marco Milani, from Italy.

Jack Newton used his 25-inch f/5 reflector and an SBIG ST-6 CCD camera to capture the subtle hues of the Dumbbell Nebula (bottom). The color CCD image is a composite of three filtered monochromatic frames. Newton used the same equipment to record images of the Eagle Nebula (bottom left) and galaxy NGC 891 (left center).

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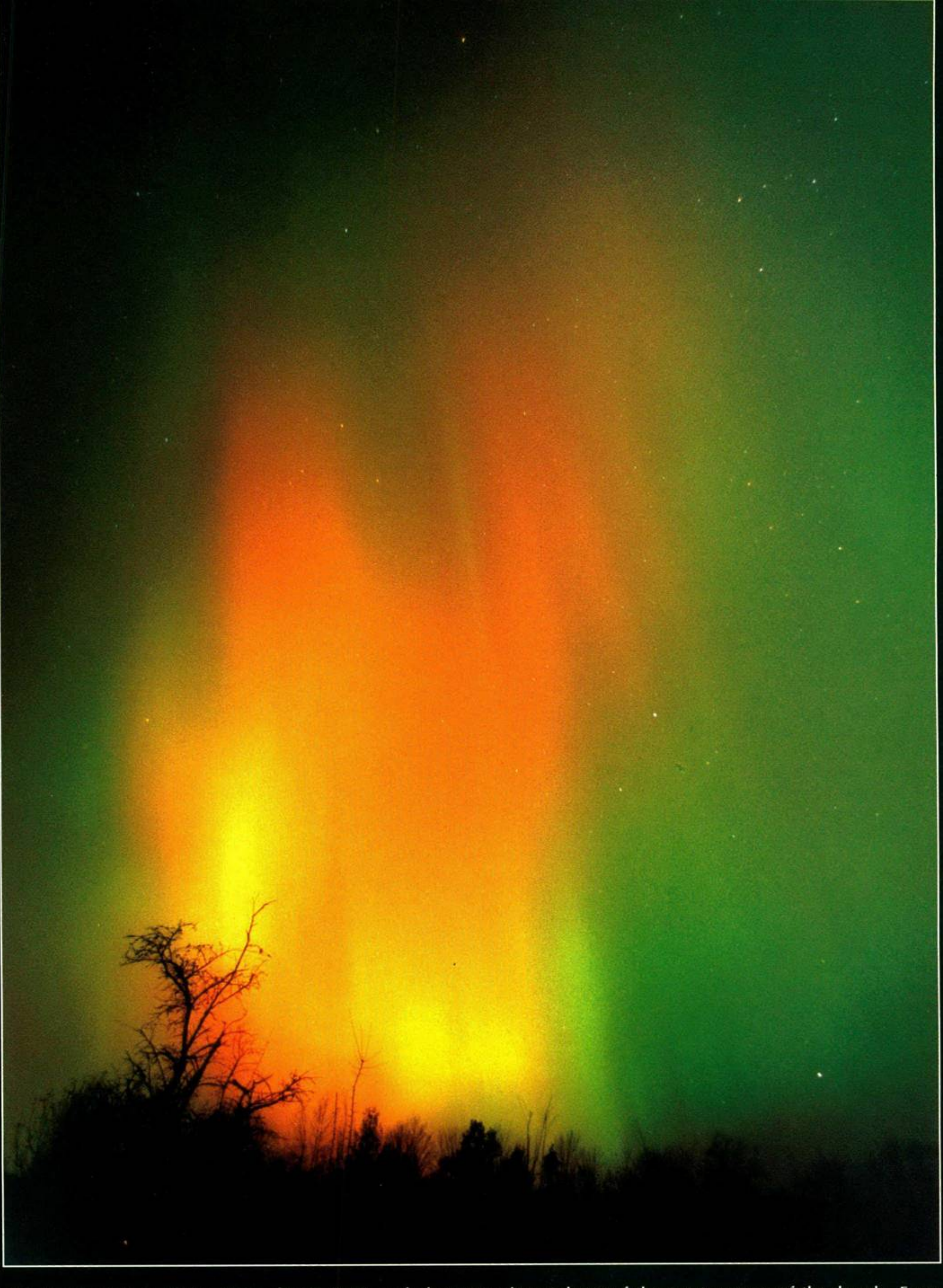

The sky erupted on Friday, November 8, 1991, and observers witnessed one of the great aurorae of the decade. From Coolsville, New York, Robert B. Slobins recorded this image of aurora curtains in the northern sky.

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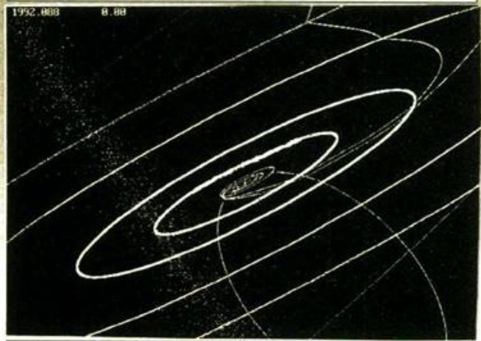

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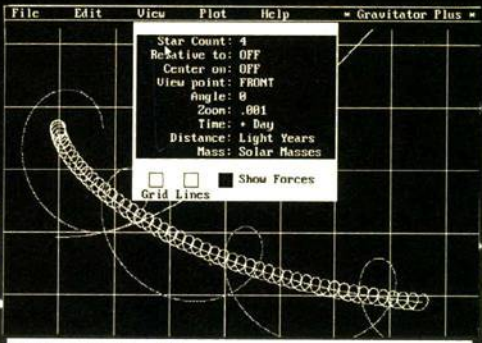

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Star Count: 4
Relative to: OFF
  Center on: OFF
 View point: FRONT
      Angle: 0
       Zoom: .001
       Time: + Day
   Distance: Light Years
       Mass: Solar Masses
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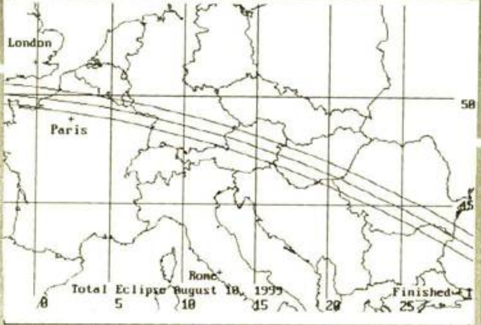

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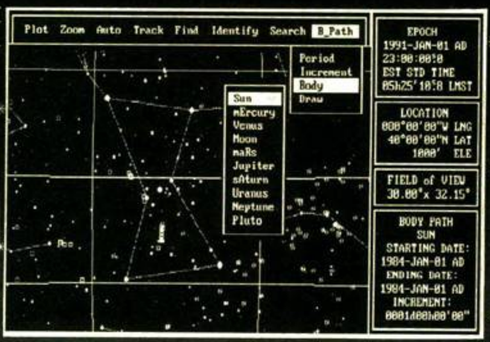

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EPOCH
1991-JAN-01 AD
23:00:00.0
EST STD TIME
05h25'10.8 LMST

LOCATION
000°00'00"W LNG
 40°00'00"N LAT
     1000'  ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"
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Partial Solar Eclipse
Magnitude: 0.170  Obscuration:  0.3%
LAST CONTACT
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(***   NGC 3034  Located at TARGET   ***)

NGC# ObjTyp Cst  Mag Type        Size   R
3034 Galaxy UMA  9.5 Am          11'x 5'

(CIRCUMPOLAR)   TT: 17h35'28.3   (CIRCUMPOLAR)
```

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GLORIOUS SKYLORE

The Glorious Constellations, by Giuseppe Maria Sesti, (Abrams, 1991), ISBN 0-8109-3355-1, 495 pages, sewn binding, hardcover, $95.

This is a large and expensive coffee-table book devoted to the history and mythology of the constellations. It is rich in illustrations: the 624 in black and white have been drawn from many sources, including works by such famous astronomers and artists as Johann Bayer, Albrecht Dürer, Johannes Hevelius, and Gustave Doré. The book also includes a superbly reproduced 48-plate color section showing the beautiful constellation frescoes painted in 1575 on a ceiling in the Villa Farnese in Caprarola, Italy.

The first 120 pages are an illustrated history of astronomy from the earliest records in the Middle East through the Renaissance, the point when modern astronomy began. The second part of the book is a rundown of the main celestial myths, arranged by constellation. The descriptions focus largely on Greek and Roman myths, but Sesti explores other mythologies briefly. The reproduction of the woodcuts and engravings is excellent, and the historical text is readable enough, if not very detailed. While the book would never do as a detailed reference work, it is a pretty production all in all.

Any prospective purchaser, however, should be aware of a flaw in the book's manufacture: someone unfortunately chose to give the binding a rigid spine. This means that any owner who opens his book frequently will soon find the copy working loose at the cover hinges. This is a flaw which often surfaces in big, thumpy, pretentious art books. Considering the steep price of the book, I felt choosing a rigid spine indicated a certain contempt for those who buy their books with the intent of actually opening and reading them. — *Robert Burnham*

Amateur Astronomy

Planetary Nebulae, by Steven J. Hynes, (Willmann-Bell, 1991), ISBN 0-943396-30-1, 264 pages, sewn binding, hardcover, $24.95.

Planetary nebulae might be called astronomy's Cheshire cats. These ghostly clouds of gas are thrown off by certain kinds of stars as they evolve. For a cosmically brief time until they gently dissipate, planetary nebulae glow softly from the energetic radiation coming from their star. Many are visible in backyard telescopes, among them the famous Dumbbell Nebula (M27) in Vulpecula.

Hynes has compiled "a practical guide and handbook" which includes finder charts for 253 planetaries and a catalog of them containing 1,340 entries. Chapter 1 explains how they were discovered, chapter 2 discusses the astrophysics of planetaries, and chapter 3 looks at other objects that can mimic them. Chapters 4 and 5, which contain the bulk of the book, tell you how to observe these objects and present the catalog and charts.

Lightweight Giants, by Steven Overholt, (Owl Books, 1991), no ISBN, 94 pages, paperback, $11.99 (+80¢ shipping). [Publisher's address: Box 154, San Juan Capistrano, CA 92693.]

The lightweight giants of the title are large, portable reflecting telescopes on Dobsonian-type mountings. The book was written "for those who have always wanted a large telescope of their own, but have lacked sufficient funds or confidence to realize their dream."

The text is a long discussion of the materials and design philosophy of the 20-inch Magellan scope built by Overholt as an outgrowth of the comnmercial Obsession telescope designed and manufactured by David Kriege. Although the text is specific to Overholt's design, much of the information would be helpful to anyone interested in building a large Dobsonian.

Meteorites

The Meteorite & Tektite Collector's Handbook, by Philip M. Bagnall, (Willmann-Bell, 1991), ISBN 0-943396-31-X, 160 pages, sewn binding, hardcover, $24.95.

This is a short but thorough guide to meteorites and tektites, with a strong emphasis on collecting, preserving, and displaying them.

Chapters 1 and 2 provide a history of meteorite collecting and suggest sources for buying meteorites and places to locate them. Chapters 3, 4, and 5 discuss the structure and appearance, composition, and classification of meteorites. Chapter 6 explains how to preserve specimens and curate a collection. Lastly, chapter 7 examines tektites alone. Rounding out the book are an index, a glossary, a bibliography, and address lists of suppliers and famous museum collections.

Planetary Science

Uranus, edited by Jay T. Bergstralh, Ellis D. Miner, and Mildred Shapley Matthews, (University of Arizona Press, 1991), no ISBN available, 1076 pages, acid-free paper, sewn binding, hardcover, $65.

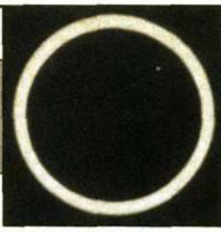
In many amateur astronomers' minds, Voyager 2's encounter with Uranus is inextricably linked with the Challenger disaster, which came just two days after the spacecraft made its close encounter with the planet. Adding to the sense of anticlimax was the fact that the intended star attraction turned out to be Uranus the Dull, with a family of satellites far more visually interesting than it was. And sealing the fate of Uranus in the popular mind was Neptune the Glorious, Voyager's next target, which abounded with features on the planet, its rings, and its one big moon.

But if Uranus got a bum rap from the general public, that's not how scientists saw it. This tome from the excellent University of Arizona Press Space Science Series reprints the papers given at a professional Uranus conference after the encounter. In a sense, it wraps up the first round of science discoveries at Uranus. While nearly all the papers are highly technical, there are some summaries which are accessible to readers who aren't new to planetary science. Yet considering the technicalities and the stiff $65 price, most backyard astronomers will probably opt to sample this book in a well-stocked library.

Astronautics

NASA Visions of Space, by Robin Kerrod, (Courage Books, 1990), ISBN 0-89471-853-3, 168 pages, sewn binding, hardcover, $19.98.

This oversized book presents a history of NASA as shown in the paintings and drawings that the agency commissioned under its NASA Art Program. For manned space flight, it's all here in color — from Mercury's earliest days to the yet-unbuilt space station. But disappointingly, the unmanned missions, which have taught us more about the solar system, receive relatively little coverage. ☐



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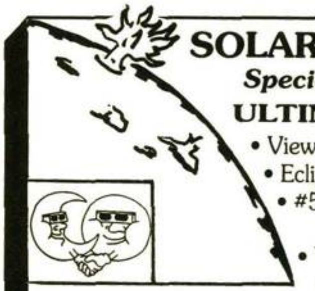

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ASTROPHOTO OF THE MONTH

Barred Spiral Galaxy NGC 1300 in Eridanus. Photo by David Healy using a Lumicon Giant EASY-GUIDER and hypersensitized 2415 film. 1 hour exposure, Celestron-14 at f/[illegible].

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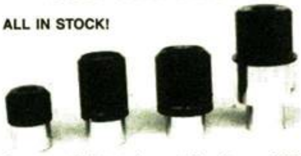

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ASTRONOMY February 1991

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Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

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Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

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Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

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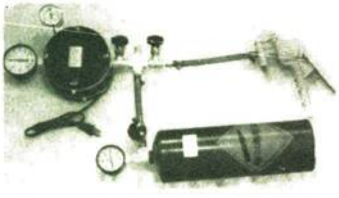

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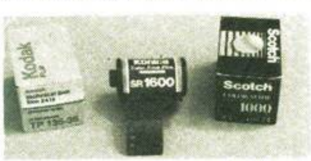

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PREMIER 2080
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Meade Premier 2080 Model 50SD

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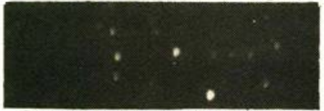
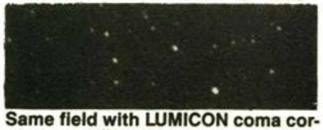


Coma 1 inch off-axis 17½" f/4.5



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2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
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2" Extension for viewing	**$26.00**

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1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x Multiplier Lens	**$235.00**

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Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher, C-6, Meade 312, 321 refractor	**$30.00**
2" LUMICON EASY-GUIDER (state camera)	**$169.50**

GREAT "HOW-TO" BOOKS

Are you considering buying or building your own telescope? The type of telescope that will be best for you depends upon many factors. ☐ **Telescope Optics, Evaluation and Design $24.95** starts with the basics and goes on to explain the advantages and disadvantages for practically every type of telescope of interest to the amateur—the ☐ **Optional IBM-PC Telescope Design Software $24.95** check here ☐ for math coprocessor version. (sold only to purchasers of the book) enables you to design and raytrace your own custom telescope. If you decide to make a Newtonian or Cassegrainian telescope ☐ **How to Make a Telescope $19.95** has, for more than 30 years, been consistently rated as the most complete and accurate book on the subject. ☐ **Microcomputer Control of Telescopes, $19.95** is a comprehensive guide that provides both the theoretical and practical considerations to computer control of telescopes. For nearly 20 years and 200+ issues the *Maksotouv Circulars* covered a wide variety of topics of interest to the advanced amateur telescope maker. The best of these articles have been assembled into **Advanced Telescope Making Techniques,** ☐ **Volume 1 — Optics, $19.95,** ☐ **Volume 2—Mechanical, $19.95.**

For less than the cost of two rolls of processed color film ☐ **Astrophotograpy**, *Featuring the fx System of Exposure Determination*, **$18.95** will start you on the fascinating and rewarding pursuit of astrophotography—first with a simple tripod mounted 35mm camera—then with telescopes. Because this book concentrates on exposure determination, trial and error are reduced to a minimum. ☐ **Astrophotograpy II, $18.95** is a more advanced level book dealing with films, developers, filters and optical systems with greater detail than other books. ☐ **Introduction to Observing and Photographing the Solar System, $19.95** describes Don Parker's photographic technique that has enabled him to make world class planetary photographs from his home in Coral Gables, Florida. This book won the Astronomical Society of the Pacific's "Book of the Year" award for 1989 plus it has the added bonus of describing the whole range of planetary and lunar observing methods. ☐ **CCD Astronomy**, *Construction and Use of an Astronomical CCD Camera*, **$24.95** describes CCD cameras in such detail that you can build and program your own camera—or learn the details that will enable you to make an intelligent purchase of a commercial camera. ☐ **Introduction to Astronomical Image Processing**, *A Comprehensive Guide to CCD Image Enhancement for the IBM-PC and Compatibles*, **$29.95**. *is for you if you have an IBM-PC with a CGA, VGA or EGA monitor—you can explore the fascinating world of image processing with this book-software combination. The manual is clearly written and images are provided to practice on. Written in MS-QuickBASIC both executable and source code files are* provided. Have you ever wanted a good star atlas that was big enough to be useful but small enough to tuck away in a suitcase, briefcase or even under the seat of your car? Wil Tirion's new ☐ **Bright Star Atlas 2000.0, $9.95** is just that kind of atlas. It plots the entire Yale *Bright Star Catalog* plus a selection by Brian Skiff of the Lowell Observatory of 500+ Deep sky objects—including all the Messier Catalog—that are visible with binoculars or small telescope. Once you have learned your way around the night time sky there is no better atlas than the World acclaimed **Uranometria 2000.0,** ☐ **Volume 1,** *The Northern Hemisphere to –6 degrees* **$39.95,** ☐ **Volume 2,** *The Southern Hemisphere to +6 degrees* **$39.95.** Together these two volumes plot more than 330,000 stars and 10,000+ deep sky objects. In addition to the titles listed here, Willmann-Bell publishes many other books. Further, we carry well over 1,500 astronomy related titles from other publishers. Our catalog is free with an order but the ☐ **Willmann-Bell Catalog by itself is $1.00**

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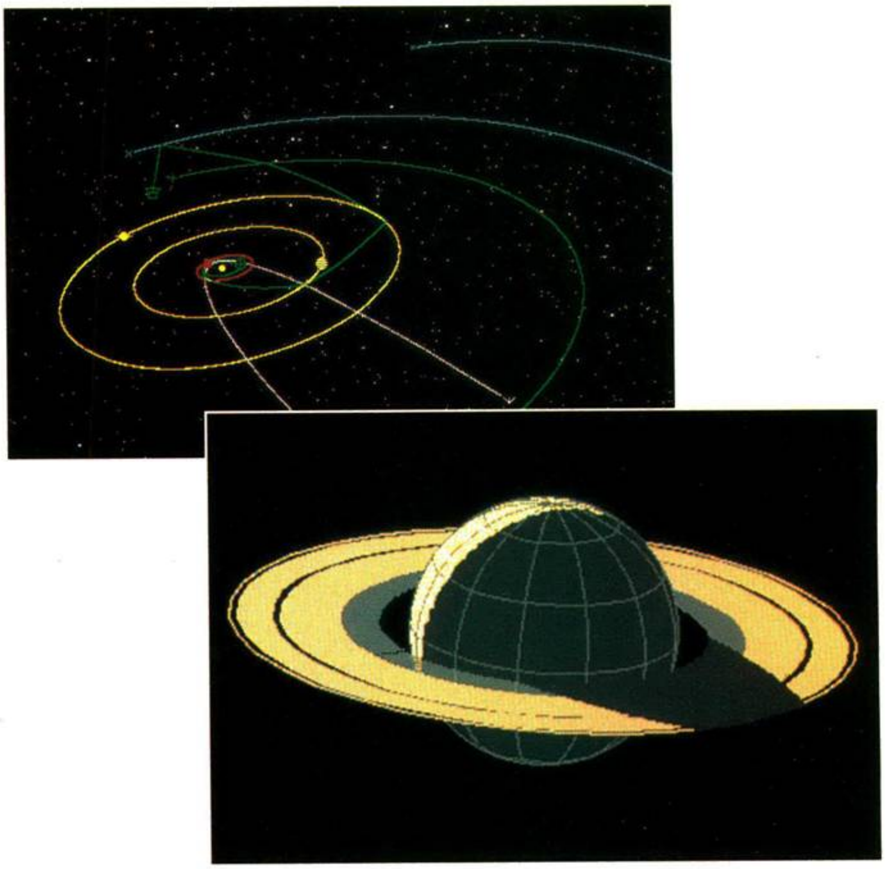

***Voyager, the Dynamic Sky Simulator™ for the Amiga™**, Carina Software, 830 Williams Street, San Leandro, CA 94577, (510) 352-7332. $124.95 plus shipping. Extension disk 1 and 2: $30 each. Base program requires Amiga computer with minimum one megabyte of RAM, two disk drives, and AmigaDOS 1.3 or 2.0. Math coprocessor not required.*

Amiga computer owners can rejoice! One of the most successful and powerful astronomy programs for the Macintosh line of computers is now available for Amigas. The new version of Voyager contains features not available in the current Mac program (version 1.2), features such as the ability to hide the control panel for a panoramic view of the sky alone, mythological sky figures, a Milky Way outline, a Moon map and, most significantly, a color display.

Voyager for the Amiga retains the best features of the Mac version: the mouse-driven point-and-click interface and the ability to view the motions of the Sun, planets, and comets from any point in the solar system.

VOYAGER FOR THE AMIGA offers simulated views of the stars and planets as seen from any point on Earth or in the solar system.

The base program comes with a database of 9,100 stars and 1,200 deep-sky objects. Extension Disk 1 adds another 17,000 stars to magnitude 7.5 and an additional 3,000 deep-sky objects. It requires 1.5 megabytes of RAM. Extension Disk 2 adds 62,000 stars to magnitude 8.5 and requires 2 megabytes of RAM, a hard drive, and a 68020 or 68030 processor.

Meanwhile, Macintosh owners can take heart in the knowledge that version 2.0 of Voyager for the Mac (with color!) is promised for later in 1992.

***CCD Data Acquisition and Reduction package**, Unified Software Systems, P.O. Box 21294, Columbus, OH 43221. Price information not available. Demonstration disk available. Minimum requirements: IBM PC/AT or* *compatible, 640 KB memory (512 KB free), EGA or VGA display, and DOS 3.0 or higher.*

This suite of three programs is designed to operate with Spectra-Source's Lynxx CCD camera. One program, CCDRT, runs the camera. CCDRED permits some simple analysis of the CCD image, including extraction of stellar magnitudes, and CCDPHOT provides extinction corrections and filter transformations for magnitudes measured with CCDRED. Unified Software Systems provides several data files so you can try your hand at stellar photometry data reduction — and simple image processing — on your home computer.

***Destination: MARS!**, Compu-Teach, Inc., P.O. Box 9515, New Haven, CT 06534. $59.95, includes Van Dam's Mars Unfolds map. Available for IBM PCs and compatibles (384 KB required), Apple II (128 KB required) and Mac and Apple IIgs (1 MB required).*

A mission to explore the mineral wealth of Mars is the theme this educational program uses to ask students some simple math and science questions. As a space shuttle pilot, you perform several "experiments" (multiple-choice questions) and eventually lead a mission to Mars. Sound accompanies various tasks and events, including spacecraft launches.

The program is advertised for ages 11 to 17, but the program will not challenge the young people of this age bracket that I know. For example, the launch sequence is automated except for occasional "pilot" inputs, which students copy directly off a card. Students will discover quickly that the companion booklet contains the answers to most of the questions. And unfortunately, the question material is too advanced for an audience younger than that advertised, who might find the game portion more fun.

Improperly answered questions are met only with a "computer override" signal. A second chance at answering the question with some feedback from "mission control" might encourage learning. Some basic information is missing from the manual such as how to stop the program. Moreover, the software designers should provide a mute switch so program users do not bother other students in a classroom. — *Dave Bruning*

Racing with the Moon

Join us on ECLIPSE SAFARI '92 as we follow the shadow of the moon in a comfortable jet aircraft and enjoy African land adventures.

June 22—July 5, 1992

High above the South Atlantic, we'll put you neck in neck with the total solar eclipse on June 30th! Views of totality exceeding nine minutes are possible according to our flight plan developer, *Sky and Telescope* editor Leif Robinson. A repeat of our 1990 Eclipse Flight over Finland, this is the best way — the only way — to see this event.

At Africa's tip, activities abound. Cape Town offers myriad comforts against the spectacular backdrop of Table Mountain. Private invitations to the South African, Astronomical Observatory's historic Royal Observatory and its famous observing site at Sutherland await you. Attend parties saluting starry southern skies. See where the Indian Ocean collides with the Atlantic.

Experience eclipse chasing in the grand manner. Follow in the footsteps of Hemingway with a photographic safari through private game preserves in an open Land Rover. Check into a private game lodge like world-famous Mala Mala or Kirkman's Camp after a thrilling game run in search of lion, elephant, and leopard. There's much more to savor and explore in Johannesburg and Durban. Optional extension to Victoria Falls. For a break in the journey, we include colorful Lisbon!

We have spent the last two decades refining the eclipse experience...and now we're teaming up with *Sky and Telescope* to add a whole new dimension. Join such luminaries as Dr. Fred Hess, Dennis di Cicco and Fred Espenak.

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- *World famous 8 inch 2000mm F/10 optics*
- *Meade LX worm gear drive system*
- *Meade #43 drive corrector - for easy RA drive adjustment & 12v DC operation*
- *Meade 25mm (80X) & 9mm (220X) MA eyepieces*
- *6x30 finderscope · 1¼" diagonal*
- *Wedge & adjustable field tripod*

VERY LIMITED SUPPLY **\$1049^{95}**

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Upgrade your 2080 Enhanced with sophisticated Astrophotography features

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- #62 camera adapter with your choice of T-mount **\$299^{95}**

2045D

THE SCHMIDT-CASSEGRAIN YOU CAN TRUELY TAKE ANYWHERE

4 inch 1000mm F/10 optical tube with MCOG multicoatings, equatorial fork mount with reversible DC motor drive & table tripod, 5x24 finder, 1¼" star diagonal, 25mm eyepiece, AA battery pack **$619**

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SCHMIDT CASSEGRAIN TELESCOPE SALE

The world's finest wide field Schmidt Cassegrain Telescopes - so good even **NASA** uses them! Get a 59% wider field of view & a 60% reduction inexposure times than with a traditional 8" SC scope.

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Meade's 1600mm F/6.3 10 inch 1200mm F/6.3 optical tube privides 25% more light gathering than a comparable 8 inch tube. Add to that an ultra, precise LX6 drive system and supplied with ECC hand controller, DEC motor, 26mm Super Plossl eyepiece, 9x60 RA polar illuminated finder, 2" diagonal, wedge, tripod & case & you have the best value in a large aperture wide field telescope. **$2179**

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Purchase a Meade Premier Smart Drive Telescope & Receive A $600 Accessory Package From Meade. Call For Details

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THE PREMIER SCHMIDT-CASSEGRAIN TELESCOPE FOR ASTROPHOTOGRAPHY

- 8 inch 2000mm F/10 diffreaction limited optics with Mead's exclusive SMC super multi-coatings
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COMPLETE FACTORY PACKAGE INCLUDES: Optical tube, Smart Drive, 26mm Super Plossl eyepiece, 6x30 finderscope, 1¼" diagonal, ECC hand controller, fiekd tripod, equatorial wedge, AC adapter, AA battery pack, case **\$1514^{95}**

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INCLUDES THE SAME FINE FEATURES OF THE 2080/40SD PLUS.....

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- **Two** eyepieces: 12.4mm & 26mm Super Plossl **\$1815^{95}**

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SUPER PLOSSL - Up to 52° Apparent Field
6. 4, 9.7, 12.4, 15, 20, 26mm 1¼" **63.95**
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10" EQUATORIAL NEWTONIAN

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Classic 8 is the latest in a long line of fine Schmidt-Cassegrain telescopes from the company that pioeered top quality comercial scopes.

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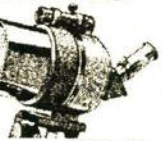

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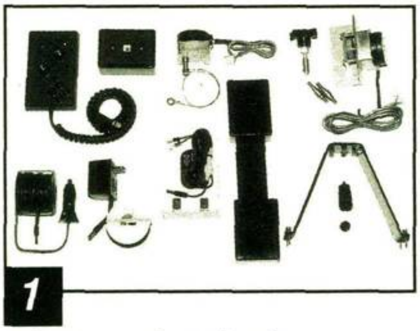

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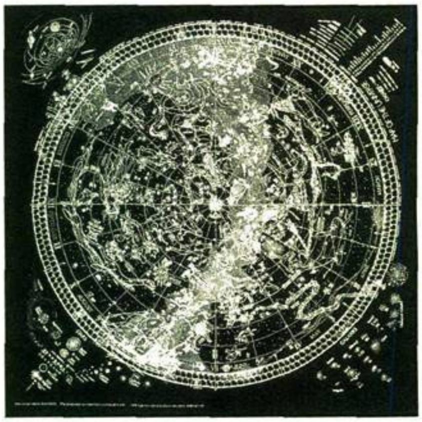

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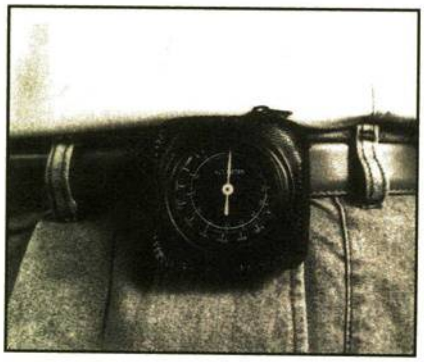

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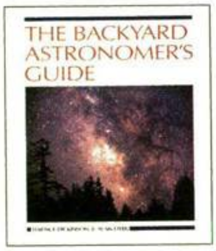

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1992 European AstroFest, Royal Borough of Kensington Town Hall, England. Contact: Peter Haille and Associates Limited, Suite 75, 49 Hallam Street, London W1N 5LN. Phone: 44-71-580-2104.

May 9
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, Public Museum of Grand Rapids, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987.

May 9
Custer Institute Family Astronomy Day, Southold, New York. Contact: Warren Hamburger at (516) 888-0072 or Barbara Lebkuecher at (516) 722-3850. ☐

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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FOR SALE — LX-6 PPEC, fork mount, JMI DEC, Meade hand controller, wedge, HD tripod, for Meade 2120. $950. Phone (504) 367-5820.

FOR SALE — ASTRONOMY, August 1973 through September 1991. $250 or best offer. Postage not included. Contact John K. Kundra, 27 Morris Court, Eaast Hartford, CT 06108.

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FOR SALE — 8″ f/5.7″ mirror, figured by Alika Herring, with documentation. Contact Bruce, P.O. Box 38, Roland, AR 72135-0038. Phone (501) 376-3021.

ANNOUNCEMENT — Central Arkansas Astronomy Club meets on the second Saturday of each month at the club's observatory. Contact Bruce, P.O. Box 38, Roland, AR 72135-0038. Phone (501) 376-3021.

FOR SALE — Celestron adjustable tripod for *Powerstar or any C-8.* $145 including postage. Contact Maurice Schuh, Jr., 1235-50th Ave. N., St. Petersburg, FL 33703. Phone (813) 527-5710.

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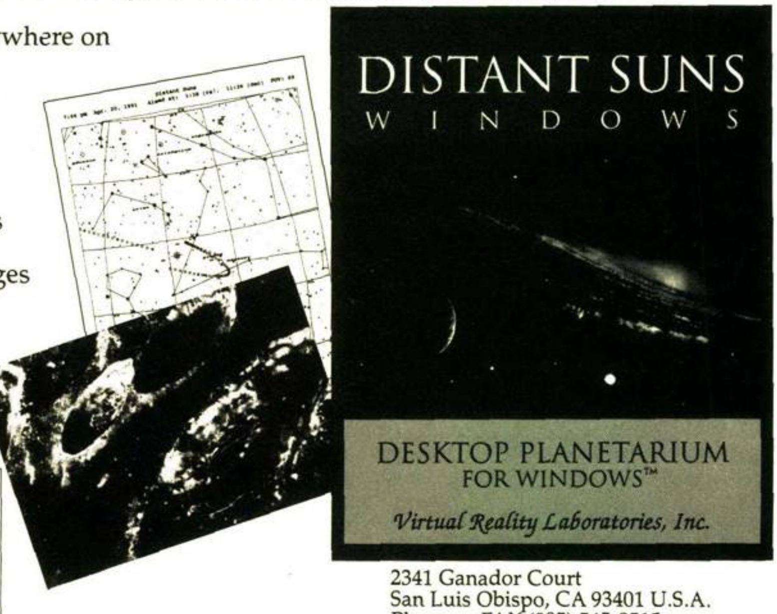

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ANNOUNCEMENT — We are planning to start a non-profit organization, International Comet Hunters' Club, devoted to hunting comets, novae and minor planets. Interested astronomers are welcome to join. Need support from the astro*nomical community: astronomical books, periodi*cals, materials, equipment and suggestions. Contact Rod Morosi, P.O. Box 2368, California City, CA 93505.

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WANTED — March 1990 issue of ASTRONOMY, mint condition please. Willing to pay more than cover price or will trade September 1989 issue of ASTRONOMY (mint condition). Contact Scott Garner, 237 Cullen Drive, Winnipeg, Manitoba, CANADA R3R 1X4.

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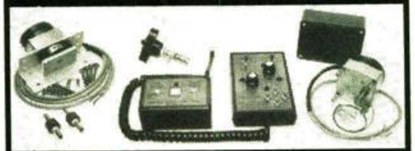

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Readings & Resources

Supernova 1987A (page 30)

"Insight into Star Death" by Richard Talcott, ASTRONOMY, February 1988. Describes what astronomers have learned about supernovae from detailed observations of SN 1987A.

Dark Matter (page 44)

The Shadows of Creation by Michael Riordan and David Schramm (W. H. Freeman and Company, 1991). A general discussion of the possible forms of dark matter and its role in the universe.

Invisible Matter and the Fate of the Universe by Barry Parker (Plenum Press, 1989) An intriguing narrative which links the astronomers to the discoveries they made about dark matter.

Astro Imaging (page 68)

"Recording the Sky on Videotape" by M. Barlow Pepin, ASTRONOMY, September 1989. An interview with video expert David Brewer on making top-notch video images.

"Video Astronomy Comes of Age" by Michael Chibnik, ASTRONOMY, August 1990. How to shoot great video images using an ordinary camcorder.

Astronomical Image Processing, by Richard Berry, Willmann-Bell, Inc. AstroIP software with manual that shows you how you can become an image-processing expert.

"Video Astronomy" and "CCD Images" by Roger W. Tuthill. These video tapes explain the potential of video astronomy and illustrate what amateurs can do with a basic camera and telescope.

Flares! (page 74)

The Sun by Iain Nicolson (Mitchell Beazley Publishers, 1982). This introduction to the Sun describes flares and possible mechanisms for their eruptions.

CREDITS

Cover: Jack Newton from three, 2-minute exposures with a 25-inch f/5 Newtonian reflector, image processing (using custom software and Aldus Photostlyer) by Richard Berry; ***p. 4:*** Jack Newton, three 2-minute exposures made with an SBIG ST-6 CCD camera; ***p. 20:*** Caltech/JPL; ***p. 22:*** Steve Saar, Center for Astrophysics and Nicolai Piskunov, University of Helsinki; ***p. 26:*** Walt Matell; ***p. 28:*** Robert Reeves; ***pp. 30-31:*** illustration by Robert Eggleton; ***p. 32:*** Tycho portrait from frontispiece of his *Astronomical Letters*, Tycho's supernova from Johann Bayer's *Uranometria*, Simon Marius portrait from frontispiece of his *Mundus Jovialis*; ***p. 33:*** Spectrum courtesy Robert Kirshner, photo courtesy NASA/ESA; ***pp. 34-35:*** computer artwork by Steve Davis; ***pp. 36-37:*** observed magnitudes to date courtesy Mark Phillips at Cerro Tololo; future predictions by Kenneth Brecher; ***pp. 38-39:*** NASA; ***p. 40, top:*** D. A. Gurnett, University of Iowa; ***bottom:*** NASA; ***pp. 41-43:*** NASA; ***pp. 44-45:*** illustration by Michael Carroll; ***p. 45:*** painting by Michael Carroll; ***p. 46, left:*** illustration by Tom Hunt; ***p. 46, right:*** Tony Hallas and Daphne Mount; ***p. 47:*** Jim Baumgardt; ***p. 48, left:*** painting by Adolf Schaller; ***p. 48, right:*** painting by Mark Paternostro; ***p. 49, left:*** illustration by Tom Hunt; ***p. 49, right:*** painting by Victor Costanzo; ***p. 60:*** James Foster and Michael Stecker; ***p. 68:*** Chris Becker; ***pp. 68-69:*** photos and CCD images by Jack Newton, cropped from a 20-minute exposure on Kodak VR1000 film with 20-inch f/5 reflector, three 2-minute filtered exposures processed with AstroIP software and composited with Aldus PhotoStyler by Richard Berry; ***p. 70, top left:*** Roy A. Tucker, 20-inch f/30 Tumaroc Hill reflector with a Sanyo VDC-3800 CCD monochrome video camera connected to a dual-frame-buffer video digitizer, image conversion and processing by Richard Berry; ***top right:*** Don Parker, eyepiece projection at f/27 on a 16-inch f/5 reflector using a Lynxx-PC CCD camera; ***p. 71, top, middle, and bottom:*** photos by Don Parker and Richard Berry, raw frame taken using eyepiece projection on Parker's 16-inch f/5 reflector using a Lynxx-PC at f/27 with a 0.3-second exposure, unsharp masking and sharpening by Richard Berry using AstroIP software, maximum entropy processing by Ajai Sehgul of DSPS, Inc., using MAXEN386 software; ***p. 72, top left:*** Don Parker using a Lynxx-PC with eyepiece projection at f/27 on a 16-inch f/5 reflector, through red, green, and blue filters, image processing with AstroIP and Aldus PhotoStyler software; ***top right:*** Jack Newton using a prototype SBIG ST6 camera and a 25-inch f/5 reflector, through red, green, and blue filters, image processing using custom software by Richard Berry and Aldus PhotoStyler; ***pp. 72-73:*** Chris Becker and Darla Galweski; ***p. 74:*** courtesy National Solar Observatory/Sacramento Peak; ***p. 75:*** courtesy Don Neidig, National Solar Observatory/Sacramento Peak; ***p. 76:*** illustration by Richard E. Hill; ***p. 77, left:*** Don Trombino, 3-inch refractor at f/32, full aperture filter, Kodak Tech Pan film; ***p. 77, right:*** Don Trombino; ***p. 78:*** Jean Dragesco, 14-inch SCT stopped to 4 inches, O.6 Å H-alpha filter, Kodak Tech Pan 2415 film, 1/50-second exposure; ***p. 80:*** illustration by Bruce Bond; ***p. 83:*** illustration by Phil Kirchmeier; photo of M35 by Robert Reeves, 8-inch f/1.5 Schmidt camera, hypered Tech Pan 2415 film, 15 minutes with a #92 filter; ***p. 84, top left:*** Richard M. Mischke, 50mm lens, Tech Pan film, 12-minute exposure, no filter; ***bottom right:*** same but a 30-minute exposure with an H-alpha pass filter; ***top right:*** Robert Reeves, Tech Pan film, 4-minute exposure, polarizer filter; ***p. 85:*** Robert Reeves, 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, 33-minute exposure, #92 filter; ***p. 89, top and bottom:*** Ivan Dryer; ***p. 90, top left:*** Marco Milani; ***left center:*** Jack Newton, 25-inch f/5 reflector, SBIG ST-6 CCD camera; ***top right:*** Gerard Therin, 4-inch f/5 lens, hypersensitized Tech Pan film, 105-minute exposure with a Deep-Sky filter; ***bottom right:*** Jack Newton, 25-inch f/5 reflector, SBIG ST-6 CCD camera, composite color image made from three filtered monochromatic images; ***p. 91:*** Robert Bunge, 35mm f/2.8 lens, 2-second exposure on Kodachrome 64 film from Manassas, Virginia, on September 29, 1991; ***p. 92:*** Robert B. Slobins.

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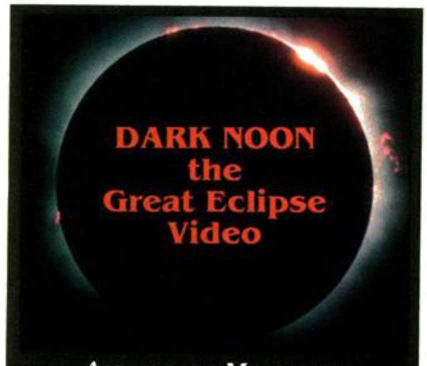

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Adorama 110, 111
ARC Software 27
Archtectual Arts 86
Astro Innovations 113
Astro-Physics 19
Astronomical Society of the Pacific ..108
Astronomics 21
ASTRONOMY Products 106, 107
Ball Photo 104
Bethany Sciences 99
BLUE SKY Pages 102, 103
California Telescope Co 25
Costa Azul Tours & Travel 104
CEB Metasystems 18
Celestron International 50, 51, 116
City Camera 114
Coulter Optical Inc 105
Edmund Scientific Company 17
Educational Video Services 113
Edwin Hirsch 18
Electrim 15
FC Meichsner Co 94
Firefly Books 79
Focus Camera 100, 101
Franklin Mint 29
Fremont, Jim 112
Future Trends Software 88
Haag, Robert A. - Meteorites 94
Helmer Enterprises 95
Horizon Travel & Tours 16
Image Check 19
Innovative Energies 16
International Dark-Sky Assoc 108
JAJ Productions 94
Jim's Mobile (JMI, Inc) 21
Los Angeles Optical 25
Lumicon 96, 97
Lunar Models 16
Meade Instruments Corporation 2, 3
National Air & Space Museum 86
Newbridge Communications 10, 11
NordicTrack 15
Observer's Guide 95
Orion Telescope Center 12, 13
Parks Optical 82
Reader's Exchange ..17, 19, 86, 110, 113
Santa Barbara Instrument Group 109
Scope City 56
Scientific Expeditions 99
Seeside Engineering 114
Shutan Camera & Video 14
Spectra-Astro Systems 25
Spectra Source Instruments 82
Springer-Verlag 23
Stargazers Hotline 94
Starry Messenger 104
Tech 2000 112
Tele Vue Optics, Inc 7, 9, 115
Thousand Oaks Optical 86
Tuthill, Roger W. Inc 27, 95, 112
Virtual Reality 109
Vista Instruments 99
Wholesale Optics (Pauli's) 55
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Willman-Bell 98
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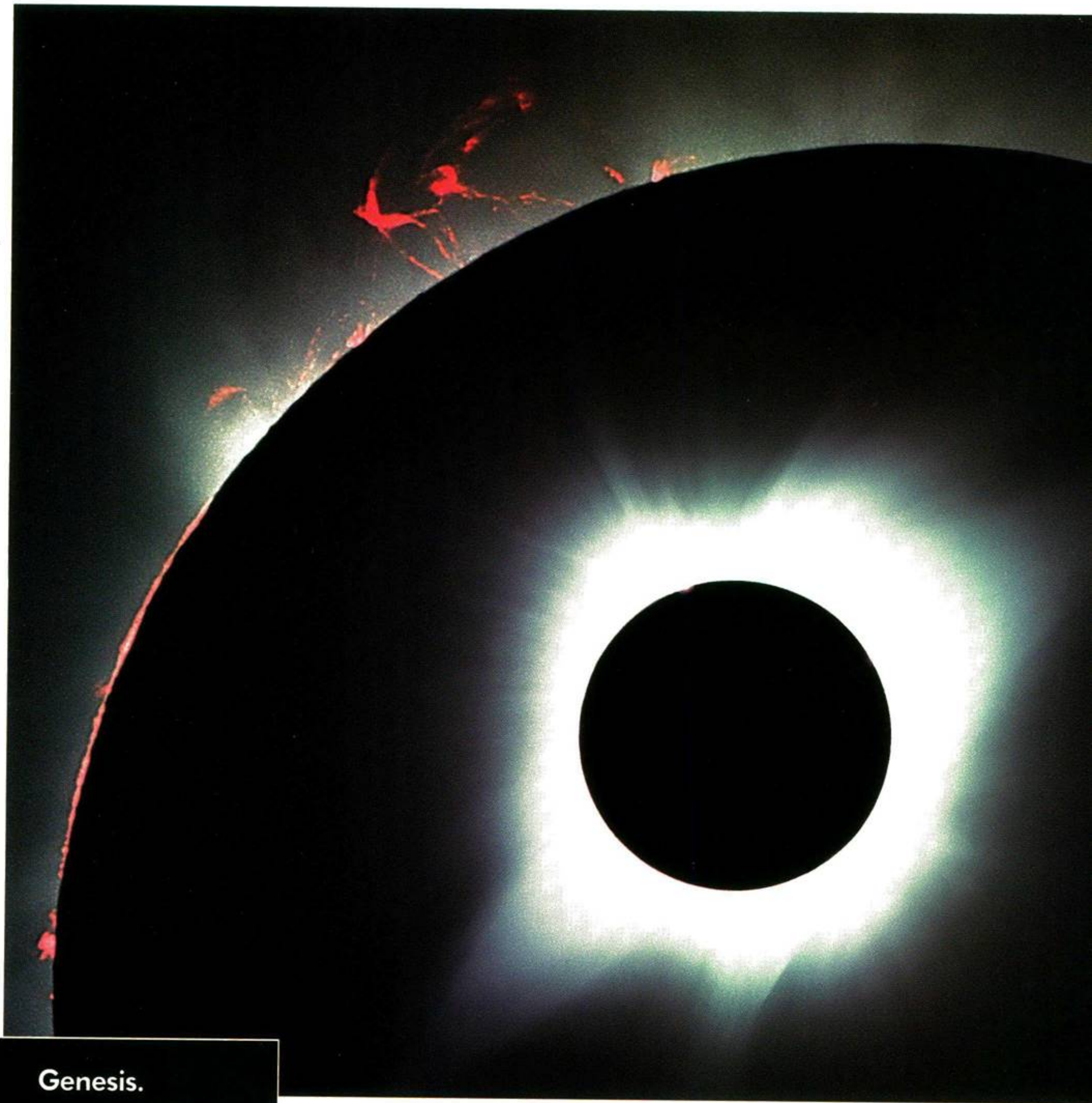

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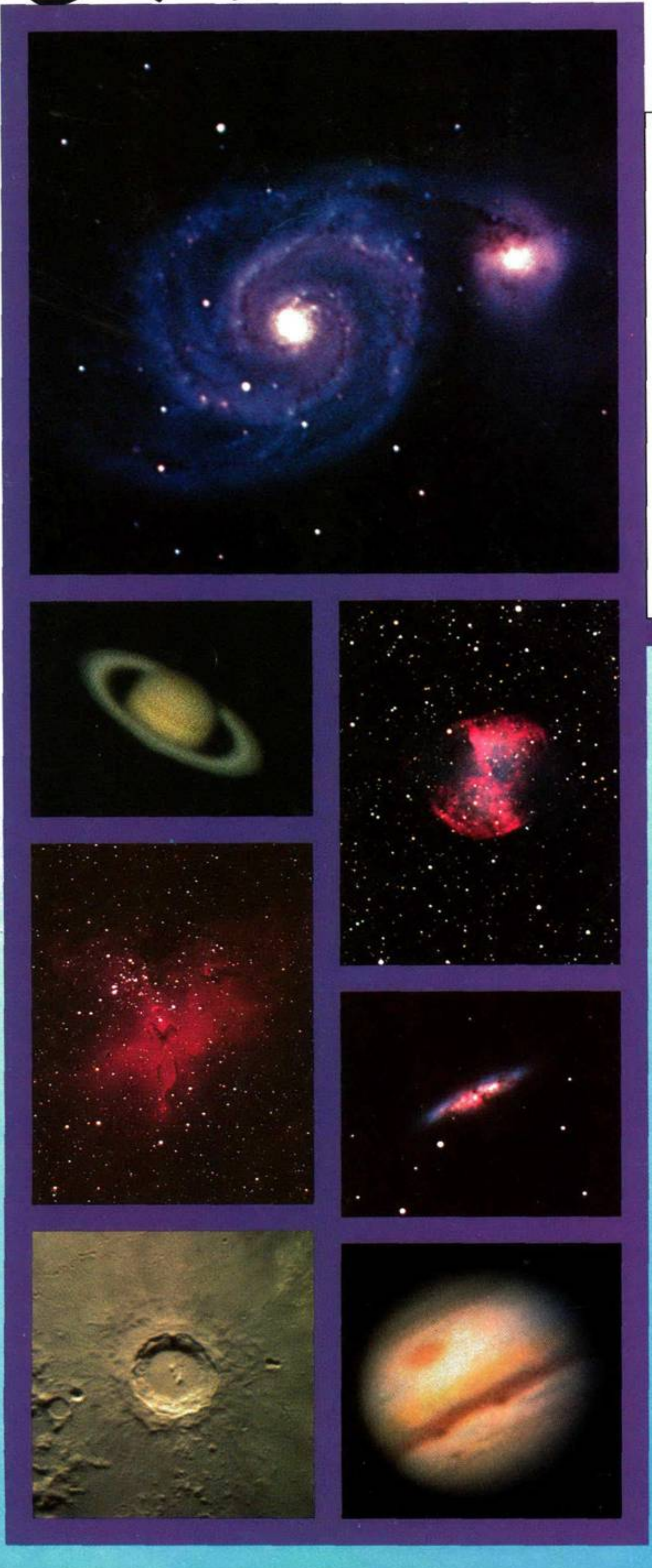

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